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THE END OF THE WORLD

BY

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Translated by MARGARET WAGNER

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THE END OF THE WORLD

Not long ago a writer, endowed with lively imagination, gravely professed the opinion that the earth as a unit is a living organism. He may be right, for the reason that it is really more difficult than we imagine to draw the line between life and death. To be sure we know that a stone is dead and that we live. But on what do we base this distinction? The usual reply is, on voluntary movement, on sensation, on consciousness. However, the greater part of the human body consists of bones; these cannot of themselves move voluntarily, and they have neither sensation nor consciousness. The bony framework of the earth is the globe itself. Upon the surface of this globe are various life-forms all of which have developed from isolated single cells. In the course of time, especially since the appearance of man, these are uniting more and more as coherent parts of an organic whole. As a matter of fact the single cell is quite similarly the starting-point of all life-forms. Gradually the functions of originally uniform cells begin to differentiate. Thus a cell-colony arises

much as men form colonies. And as in these colonies the liberty of the individual is not forfeited but only partially restricted through his obligations to the community, so likewise every cell of the human body retains some degree of freedom; indeed millions of them, for example the blood corpuscles, seem wholly free except for being driven by the common force of the circulation. They throng hither and thither in the veins as do men in the crowded streets of a city, and here and there one lodges itself where it can contribute to the upbuilding of the whole. In brief such analogies could be multiplied a thousandfold.

However they are in truth nothing more than clever comparisons. According to the eternal changeless laws of nature, dead as well as living matter is bound to continue always to unite organically. Nothing harmful can persist for any length of time since by virtue of its harmfulness it must destroy the organism in which it appears and therewith also itself. Therefore the useful must develop ever higher, must gain ever more domain and power, because it is the more lasting. In this respect then there is no distinction between living and dead forms. Everywhere, in the stellar systems as well as in the minutest

molecules that can be formed of chemical atoms, and again in the cellular tissues which upbuild living bodies, there rages an endless struggle for the survival of the fittest; and everywhere the less fit yields place to the better. For this reason we find in all phases of existence the universal phenomena of birth, growth, maturity and also of decay and death. Stars and celestial systems rise and set.

Our planet too. Though the earth-life joyous and care-free has developed in upward course since millions of years ago, the decline is bound to come.

But how can that come to pass? We make our plans for years in advance, statesmen for decades and centuries. Nature round about us, the result of uninterrupted development for millions of years, has vitality for further millions and millions of years. Who could believe that there should ever be an end? Wherefore this evident struggle for ceaseless progress which inspires even inanimate nature, if all is destined to end some day? Wherefore are we all doomed to die? We cannot do better than reply with Mephisto: Because everything which exists is worth being destroyed.

Everything is worth being destroyed. In other

words, nothing is good enough to live forever. Ours is not a perfect world, and therefore the old must die in order that the young, that which is more perfect or at any rate capable of greater perfection, may live. Thus death becomes a thing necessary and useful in the evolution of the whole; the destruction of one celestial body contributes to the progress of the rest of the universe.

But how can this be? Are there then, in spite of the millions of miles that intervene between the nearest heavenly bodies, inter-relationships that affect something besides their movements or, at any rate, their illumination? Would the development of the solar system be changed in any way, if the earth together with everything upon it were to be so crushed as to be reduced to a mere formless cloud of dust revolving in its orbit around the sun?

Such questions clearly cannot be despatched with a word or two of reply. And to the majority, perhaps, these inquiries will seem frivolous, for why should we be concerned about the rest of the solar system or indeed about the rest of the universe, if our planet is doomed to perish? Is a dying man concerned to know what will become of the world after his death?

However, our earth is evidently not as yet in the throes of death, but on the contrary in the bloom of earliest youth; and accordingly it is but natural that we should feel interested in considering its future destiny just as we, as individuals, occasionally wonder how long a life lies before us, and how the end will come. In moments consecrated to such grave reflection, we hear in the infinite silence the flapping of the wing of Eternity, of which the hours that whirr past are but a vanishing fraction.

The world; what then do we mean by "the world," the future destiny of which is the theme we propose to consider? The term, "the world," in its widest significance embraces all that exists, the universe in its entirety. Now that can never end. Whatever is in the world can merely change its form. Only a part of the All can be destroyed. And what do we mean by "being destroyed?" For not even this part of the All can be annihilated. It can cease to be what it has been and become something different. To say that it is destroyed, means that the order which hitherto prevailed in it has stopped; that the material which formerly upbuilt its structure has decomposed into the original elements. Both construction and destruction are the work of natural

forces which are eternal and changeless in their nature and in their operation. How could it be possible that these forces, after working for millions and millions of years at the upbuilding of a planet, should reverse their course and become agents of destruction, notwithstanding the fact that they themselves, as well as the material wherewith they built, remain absolutely unchanged. Again we reach the same conclusion: namely, that there is no such thing as actual destruction even in the sense of a gradual decay of an organization in a given part of the universe, provided the decay is thought of as general and the destroying force is not balanced by an upbuilding one. Natural forces, as they follow the course which they have pursued from all eternity, can destroy only here and there an organization that stands as a hindrance in their way. Nature tears down in order to rear a nobler structure. If it were otherwise, if things did not tend on the whole toward system and order, then long ago in former ages, the natural forces, in themselves unchangeable, would, since they have been at work developing the universe, have destroyed all order as we know it; a different order would now prevail, which again would have to be in harmony with these

natural forces. To repeat: *Nature cannot annihilate what has once been upbuilt, at least not in its entirety;* Nature permits decay in order to upbuild in grander style.

In that we must die, we all have to sacrifice our lives to the general advancement. We must take this truth more to heart so that the terrors of that unavoidable passing away may be lessened. Accordingly in order to learn more about the function of death in the evolution of the world, it is proposed to consider this phenomenon on a larger scale in its aspect of cosmic decomposition.

It has been shown above that an *end of the world* is impossible; and likewise that the destruction of the organization of the entire universe is impossible. We have seen further that at a given time decomposition can take place in a part only of the universe. Now we have set ourselves the task of studying the process of cosmic decay. And since we must confine our discussion to some part of the world, we will choose our earth because we know it best and because we feel something of a personal interest in its destiny. But in doing so we must bear in mind that the earth is in truth only a subordinate part and that its fate cannot but be unintel-

ligible without reference to the larger whole.

Moreover in considering the destruction of the earth, now that we have assumed for ourselves the central position of interest, we shall take account only of those catastrophes which involve the destruction of the human race. Whenever an unusually vehement storm rages and shakes our habitations to their foundation as if determined to wipe from the face of the earth all the works of man, we are wont to say that the end of the world has come. And yet compared with the prodigous might of the cosmic forces which control the earth and which therefore, under certain conditions, may work for its downfall, the most destructive of tempests seems snail-paced. One must consider that in the case of the most violent storms, the wind travels only about 130 feet a second, whereas a point of the earth's surface at the equator, in its daily revolution around the earth's axis, travels at the rate of 1522 feet and the earth itself, as it moves in its orbit around the sun, covers 19 miles a second. If the earth should suddenly come to a stand-still for but one second, everything upon it would instantaneously fall in ruins.

We all know of tremendous hurricanes which have caused the destruction of whole regions and

populations, and, for those concerned, what took place was a veritable end of the world. The myths of nearly all peoples tell of deluges which swept away everything. Doubtless there is some historical foundation for these myths. They all describe the elements as in a state of fearful uproar. Is there anything to prevent the recurrence of such phenomena, perhaps even on a larger scale, so that thereby all order on earth would be converted into chaos?

Naturally no definite answer can be given to such questions. Everything in the future is veiled from our sight. None but astronomers are so fortunate as to be able to compute natural phenomena for long periods in advance, with the absolute certainty that they will occur under any circumstances whatsoever, provided—the world does not end before the time appointed. All our observations and calculations which make any pretense to finality are valid only if things run their natural course. But we know only too well that in the actual processes of nature, abnormal and unexpected happenings intervene and set at naught all our calculations. And so the question before us is really a twofold one: In the first place, have we any knowledge of how, in the normal course of things, destruction could come

upon the human race, or upon all the life that the earth sustains, or finally upon the globe itself? Then secondly, what probability is there of an abnormal occurrence which could bring about the same results?

The latter question suggests a thousand possibilities to the imagination. Would anyone presume to declare it impossible that a hurricane should sweep even to-morrow over the earth and bury us under the ruins of our fragile habitations; or that the surface of the earth should be rent by earthquakes—the most dreaded of all manifestations of the destructive forces of nature, from which there is no escape; or that a gigantic rock should crash down from the sky and put into such terrible turmoil the atmosphere and the ocean that no living thing could withstand their vehemence? Further who knows but what there are unusually hot or cold regions in space through which our earth along with the entire solar system might be carried, so that in such extremes of temperature, life would likewise be destroyed. There are thousands of such possibilities just as there are thousands of possibilities that, through some chance which it is utterly impossible to foresee, our own life may be cut off in the next second. The world of heavenly bodies too is not

perfect; it too is not entirely protected from the fatal caprices of chance.

It would be absurd though on this account to be constantly frightened to death or, worse still, to be expecting every moment the destruction of the earth. We as individuals count on the probability of a life of definite normal length. If we could not do so, no insurance company could exist. Probability, like everything else in the world, is subject to fixed laws. In the multiplicity of occurrences, the haphazard becomes a negligible quantity and the stability of the force that controls them, becomes manifest. Probably everyone at some time has observed the meter in an electric power house, and has noticed how the indicator oscillates to and fro when the machinery is in operation because the current is broken somewhere or made to flow. It may seem natural to infer that the larger the plant the more restlessly the indicator on the meter-dial will oscillate. Exactly the opposite, however, proves to be true. In the central station of the Berlin electric street-car lines, the indicator moves scarcely at all or but very slowly since it registers only the average daily fluctuations of the current. All the busy commotion of the gigantic system is here equalized. And what we have

found to be true of the electric current, holds also in the case of the stream of humanity and again in the case of the ocean-tides of cosmic phenomena. If in one place an operation is cut off, the loss there is balanced by a gain in another place where a similar operation is begun. Everything tends to a common level.

In this sense then we can calculate upon a scientific basis the chances for or against the occurrence of destructive catastrophes, much as we compute the average extent of damage which will accrue from hail. And the same can be done with reference to the question of a partial destruction of the earth.

Unfortunately accurate numerical records of natural phenomena have been made for only about a century. To illustrate: if we had definite data as to how much longer a period must be taken each time within which a certain phenomenon of the weather—a storm, tempest or flood, for instance—has occurred increased in area by a given amount, we could calculate how many thousands of years would be required for a deluge to take place large enough to cover Europe. If then so many years had in fact elapsed since the last one, we should be justified in saying that another deluge of the proportions referred

to, was due. Whether it would actually appear is quite another matter. I have alluded to this method of calculation because in many cases where the laws governing the phenomena are as yet unknown, it has been employed with excellent results. Such is notably the case even in the domain of the most exact of sciences—astronomy.

Yet, although we lack accurate scientific records reaching far enough back into the past, at least mankind has preserved in memory those times when the human family was visited with unusually severe destruction. However, the traditions of catastrophes that involved the whole world as then known, all date back to the remotest antiquity when but a small part of the earth's surface was known to man. We have no way of telling how many thousands of years ago the biblical deluge occurred and what in reality was the extent of its devastations. In the case of similar myths of other peoples, we are equally in the dark. But since we can trace back the history of many civilized peoples of ancient times—for example the history of the Chinese, of the Egyptians and of the Babylonians—for at least five thousand years; and since within this space of time, there is no evidence of any catas-

trophe far-reaching enough to be called a destruction of the earth as defined above: we may confidently assume that for periods of time long enough for whole races to develop and again to be obliterated, the natural forces which control the world will probably not permit any such catastrophes as will threaten the existence of the earth.

Accordingly the tremendous effects which are for the present under discussion are perhaps beyond the power of the forces of nature in so far as they operate under terrestrial conditions, that is, in so far as no cosmic influences intervene. At any rate now that we have given more attention to the consideration of these natural forces, we may presume to attempt a solution of the problem.

Storms often sweep over half the earth. We can trace their path from continent to continent. Warnings of coming storms, sent over the trans-Atlantic cable, seldom prove misleading. Might not such a storm sometime lay waste all Europe? In order to answer this question, we must first consider how storms arise.

For obvious reasons, I cannot stop here to give an extended lecture on meteorology. Probably every one knows that the movements of the at-

mosphere serve to equalize the distribution of heat upon the earth's surface. Except for certain small fluctuations, to which I shall refer later on, the sun sends us always the same amount of heat; but because of the irregularity of the earth's surface, the different parts receive varying quantities of it. The position of the earth's axis, relative to its orbit around the sun, causes the difference of zones. If the earth's surface were entirely level and if there were not an unequally distributed body of water upon it, this difference of zones would cause a steady circulation of the atmosphere between the equator and the poles. This we find actually to be the case, though only in a rough and general way. Moreover, the revolution of the earth around its axis causes the air to lag behind, thus producing steady east winds at the equator. All these conditions would remain constant but for certain peculiar influences that disturb the regularity of these movements. Therefore if we have any ground at all for apprehension, it must be on account of these influences. As has been indicated above, they are due to the configuration of the earth's surface. If that were fixed and unchangeable, the effects produced by it would likewise be so. Thus a stable equilibrium would

long ago have been reached. But just as a pendulum which has received but a single push, oscillates for some time about its position of rest, so air currents once deflected out of their wonted course are not easily restored to rest. And so one sees influences reinforcing each other in one place, in other places balancing each other. Violent storms are at times the outcome. But it is clear that, considering the stability of the causal factors, their maximum vehemence must have a definite limit. This limit must have been reached at some time during the long period, reaching far back into prehistoric ages, which, for present purposes at least, lies open to our view. Since the earth was not thereby destroyed, we have no reason to be apprehensive in regard to storms, at least in so far as they are caused by the sun's heat and by terrestrial conditions. Furthermore the phenomena that sometimes attend storms—as thunder and lightning, cloudbursts, hail and floods—for the same reason cannot exceed a definite maximum of vehemence. All these effects may be compared to the eddies on the edge of a calm unruffled stream.

But what of those terrible outbreaks from the earth's interior known as earthquakes and volcanic eruptions, which in late years have so often

thrilled humanity with horror? We know how on the 8th of May, 1901, an insignificant and seemingly harmless volcano swallowed up in less than one minute 50,000 human beings. That was a veritable end of the world for the unfortunate city of St. Pierre on Martinique Island. Nothing survived; not a single blade of grass was spared. All that man and nature had fashioned in centuries, the myriads of marvelous organisms which contributed to the symmetrical upbuilding of the whole—all this was in one instant reduced to chaos. Deeply moved by such manifestations of nature's power, we stand in the presence of these catastrophes which but too frequently mar the pages of history. Scarcely 18 years before the destruction of St. Pierre, in 1883, again through the eruption of a small volcano—the Krakatoa in Sunda Strait—40,000 human beings lost their lives. Even more than the eruption of Mt. Pelée, this fearful visitation must have had for its victims the semblance of an end of the world. The volcano itself was situated on a small uninhabited island on which it could have done no harm. The catastrophe is distinguished from that which took place on Martinique Island, through the remoteness of its effects. During the eruption, the volcano was cut in two

from the very top, thus permitting sea water to flow into the glowing crater. The consequent explosions were heard over a region larger than the whole of Europe. (The map on page 56 shows the area referred to.) The air wave which was produced by these explosions traveled six times around the circumference of the earth and caused considerable barometric variations. Through the development of gases, the sea water had been forced back out of the crater. In consequence a tidal wave was set in motion which likewise encircled the earth several times. It overflowed the coasts of the neighboring islands, swept away whole villages and drowned about 40,000 human beings. A sudden, wholly unexpected flood, it was far more terrible than the biblical deluge, the gradual approach of which could be observed. Half the island was reduced to dust and carried far away into the upper air-currents. For several days, Java and other parts of Sunda Archipelago were shrouded in total darkness. There were fearful storms. Hot rains fell mingled with disgusting mire and ashes. Is it possible that anyone who lived through those catastrophic days, did not think, as he heard the cannonading of those tremendous explosions, that the whole earth was being blown

up and that it was whirling in fragments into space?

These phenomena in Sunda Strait attracted the attention of the entire civilized world. For many years, its after-effects remained visible nearly everywhere. A large part of the very

The Half of Krakatoa which Remained Standing.

finest volcanic dust was kept suspended for years in the upper air-currents. Peculiar refractions of light were thereby produced which caused the beautiful phenomenon known as "red glows" or "volcanic afterglows," as well as those brilliant sunrises and sunsets which were also observed though in a far less degree after the eruption on

Martinique Island. A few of those dust-clouds happened to reach that region near the outskirts of the atmosphere where storms prevail which constantly whirl around the earth, and were swept along with them. When the sun's rays at night lit up these clouds of dust on account of their height, they appeared even after years as luminous night clouds the immense height of which could be determined by measurement. Thus that seeming destruction of the earth ended in an enchanting play of colors.

If then the effects of such a volcanic eruption could spread over our entire planet, it is conceivable that they might at some time involve everything in ruin. Or can we count here also as in the case of storms on a maximum limit of vehemence? Unfortunately our knowledge of the nature of volcanic eruptions is still very deficient. We are ignorant of the make-up of the earth's interior which produces these tremendous effects. All we know is that under out feet the mighty fires of a former sun still blaze. Only the earth's outermost surface has cooled sufficiently to offer a dwelling-place for living creatures. If the earth's crust were to be removed, our planet would become a star sending its light far into the celestial spaces. For doubtless every-

where in that subterranean furnace, there rages a heat which would transform solid rock into burning white liquid or into luminous clouds such as at present constitute the sun's atmosphere. It can be scientifically demonstrated that the powerful pressure exerted by the rock-strata would alone suffice to make the earth not only liquid but even gaseous except for a relatively thin crust. The earth, therefore, must be viewed as an essentially gaseous globe, hardly more than a soap-bubble, surrounded like it by a liquid coat over which, in comparatively recent ages, the outer crust has been formed. In the light of scientific theory, no other hypothesis is tenable.

All bubbles burst. Cannot this happen even to-morrow quite suddenly and unexpectedly in the case of our planet to which we entrust our lives so unconcernedly? With regard to an explosion resulting through pressure from within, we have little ground for apprehension. The fact that this solid crust could be formed at all in the cooling process which extended over so many millions of years is sufficient surety that it will not be destroyed by the continued operation of these same forces. Who builds slowly, builds securely and permanently. This is a universal truth, by no means limited in application

to human effort. Had there been forces at work, in the face of which the crust could not effectively maintain itself, they would simply not have permitted it to form. It is, however, conceivable that, ever since the time when the crust closed all around, inner tensions should have been thereby produced; that the crust, because it cooled faster, tended to contract faster than the interior; and that such tensions should in fact increase steadily till catastrophes result. It is further conceivable that these catastrophes should at first occur more frequently though less violently; later always less and less frequently but the more vehemently according as the crust grew in thickness and in resistance-power. According to this view, we should now be living in a period in which the explosion of the earth as a result of this contraction, was to be feared every moment.

Serious confirmation of this view is afforded by the appearance of our nearest neighbor in the solar system, the moon. It really looks exactly as if it had once upon a time cracked like a glass ball. As is well known, the half of the moon visible to us is dotted with innumerable craters. In my opinion, however, these have not been produced by conditions which are directly comparable to those of our own volcanoes: later on, I

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The visible half of the moon is covered with craters.
See page 27.

shall return to this point. From a number of these craters extend streamers, fissures which are arranged like radii around these ring-shaped hills. From Tycho, a large ring-shaped mountain near the moon's south pole, these fissures spread out over nearly the entire visible half of the moon. The accompanying illustration (a copy of an excellent Parisian original) shows them plainly. However, these streamers are at present no longer actual yawning fissures for they are not at all visible when the sun's rays strike obliquely, whereas, if they were really open clefts, they would stand out most distinctly under these conditions. Only when the sun's rays are vertical, that is at full moon when all relief configurations are invisible, because there are no shadows, do we see these luminous ray-like streamers eradiating from the craters. If our earth should suddenly burst in similar manner, the earth's liquid interior would immediately emerge through the fissures and fill them. What overflowed would spread luminous streamers over the surface without however producing noticeable elevations. Now we know that when lava is ejected very suddenly from our volcanoes and therefore cools unusually fast, it frequently hardens into a shiny black substance of glassy

appearance, called obsidian. Such a sudden bursting of the moon's crust as we here presuppose fulfils the conditions for the formation of obsidian. Accordingly there is no other explanation for the phenomenon of the moon's streamers than that the moon's crust has cracked open at some time and that the fissures were then filled up immediately with shining obsidian or some other glassy formation. Indeed as the moon has several independent systems of streamers eradiating from different centers, it is likely that the crust has cracked not only once but several times.

The moon is made of the same material as the earth. It was originally a part of the earth and therefore the two bodies resemble each other in the character of their development, as do mother and daughter. Whatever has happened to the moon may also happen to the earth. Accordingly it is at any rate of significant interest to us to learn how the moon developed these fissures. Toward this end, two English astronomers, Nasmyth and Carpenter, performed an experiment with a glass sphere which they filled with water, afterward closing up the opening with melted glass. When the sphere was heated, the water in the inside expanded more than the enveloping

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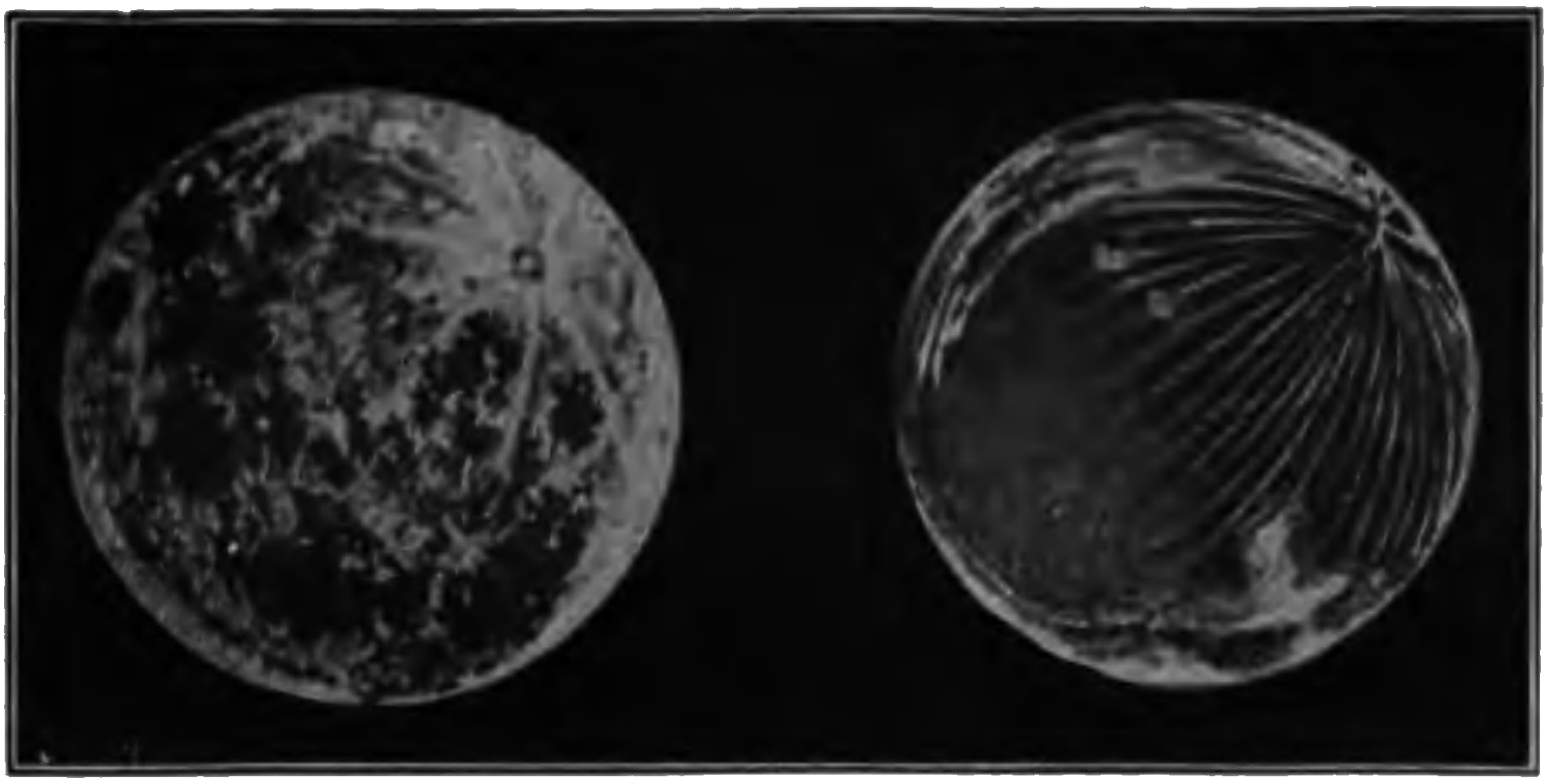

The moon, showing the crater Tycho with its radial system of streamers, and a cracked glass sphere (after Nasmyth and Carpenter). See page 29.

Saturn with his rings. See page 128.

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glass. As a result, the latter cracked along lines eradiating from various points, marvelously like the streamers on the moon. (Notice the illustration.) We must concede that the experiment described above essentially reproduces the conditions which obtain when a planet cools off, that has developed a solid crust around its fluid nucleus. The effect must evidently be the same, whether the interior expands more than the shell as in the case of the glass sphere filled with heated water, or whether the crust contracts to a greater extent than the nucleus will yield. We have seen further that, under our hypothesis, the danger of the explosion of a heavenly body increases in proportion as the crust becomes stronger, in other words, older. Now, speaking relatively, we may say that the moon is considerably older than the earth. It is true also of heavenly bodies, that the smaller of two has the shorter life-span. In the case of heavenly bodies, this is a physical necessity, because the smaller body must cool off faster than the larger one. The moon is lifeless or nearly so. Only faint uncertain evidences of a subsiding activity are visible upon its surface. All this seems to confirm the view that our satellite has in fact lived through such catastrophes by which its entire

crust has been cracked nearly from pole to pole.

In regard to the occurrence of the catastrophe, there can be no doubt. We see the evidences of it with our own eyes. All other attempts to explain the moon's streamers can be controverted. It is true that the French astronomers Loewy and Puiseux still cling to the older view, according to which these streamers are composed of whitish volcanic ashes which have been strewn thus by winds. But it is impossible that winds blowing half-way around a rotating sphere should keep their direction without swerving in the least. That would be contrary to all experience and likewise contrary to theory. But it is quite a different question whether this catastrophe may have been caused otherwise than by an explosion through inner tension. For example, if those English astronomers had thrown a stone against their glass sphere, the cracks thereby produced would have had the same ray-form arrangement. And as a matter of fact such stones can strike heavenly bodies also. We shall shortly consider this matter more in detail.

But have we not already proved the necessity of such an explosion? We have: on the assumption, however, that the earth's crust is really rigid, that is, unyielding. But this is demonstra-

bly not the case. It can be proved by experiment that the hardest rock yields under even very slight pressure, if but sufficient time is allowed. Marble slabs are cut into, like some soft substance, by the posts that support them; and this merely by virtue of their own weight. Again, they bend crooked, somewhat like a plate of lead, if, when standing upright, they are weighted obliquely. Of course such effects are wrought only after centuries. And one must consider that marble is one of the hardest varieties of rock. Furthermore the pliability of a substance can be increased considerably by heating it. It was under such conditions, moreover, that our earth was formed. Where mountains have upreared their towering masses, we see strata, which as alluvial deposits originally settled in horizontal layers, now lying in folds like cloth that has been rumpled. This took place under a pressure that raised mountains and yet this pressure cannot be nearly so great as a tension which could ultimately cleave the earth's crust for thousands of miles. Without doubt then, the earth's crust will be sufficiently pliant under any circumstances whatsoever, to accommodate itself to the slow working of a steady pressure. At the utmost, occasional fissures may be produced in isolated

spots where different pressures are exerted in quite opposite directions. The earth, in spite of its solidness, is so plastic that, as theoretical demonstrations have shown, if it were not already flattened at the poles, it would become so even to-day by virtue of the centrifugal force developed in its daily rotation. And so the flattening of the earth's poles in no wise proves, as was formerly imagined, that the entire globe must at one time have been in a fluid state. Accordingly what we found to be true on a small scale in the case of the glass sphere, by no means applies without modification to celestial bodies and to vast epochs of cosmic evolution. Besides it would be contrary to all known laws of nature if, in the normal course of things, a development of any sort should end in a catastrophe. I wish to call attention to the phrase: *In the normal course of things.* For we all know only too well that, in individual cases, catastrophes occur but too frequently.

But at the same time we have seen also that, because the cooling process goes on without interruption, the earth's crust is kept in continual motion in order to accommodate itself to the constantly changing conditions. The earth is being constantly reduced in diameter through its

own weight which compresses the mass always more and more, as well as through the cooling process just mentioned. The crust therefore becomes too large. It wrinkles like the skin of an aging person. All these operations prevent the crust from resting even for a moment; and these movements, though individually insignificant for the dimensions of the earth, constitute the earthquakes which in a few seconds can involve whole regions in misery and desolation.

Of all the phenomena that threaten the human race with destruction, none gives so vividly the impression that all order in the universe has come to an end, as these fearful tremblings of the earth's foundations—that primordial groundwork than which, next to the stars of the firmament, nothing in all nature seems more unchangeable. Upon this firm foundation rest all our hopes. Suddenly without any warning, when the peaceful landscape round about is bathed in gladsome sunlight, the earth shakes underneath our feet. At times but a single shock is produced lasting only an instant. The earth's crust may be shifted sideways no more than an eighth of an inch and lifted upward a still smaller fraction. Nevertheless the force of the shock is so great that loose objects are thrown thirty

yards and more. Practically the same thing happens when you strike a blow with a hammer on the under surface of a plank which is itself immovable: sand and other light objects upon the plank may be tossed high into the air. Of all forces upon the earth, those which cause earthquakes are by far the mightiest. It is a fact that whole continents have been jarred simultaneously. And it is just in the case of such extensive earthquakes, that the center of disturbance must be sought at a great depth, six miles or more below the earth's surface. That is to say, these terrific forces can shake to and fro a piece of the earth's crust measuring over six miles in depth and hundreds of thousands of square miles in surface area. The great earthquake of Lisbon in 1755 caused the death of 60,000 human beings and redueed to a mere heap of ruins the entire city, at that time one of the wealthiest in the world. Yet the shocks were but three in number following one another within the space of five minutes. In these five minutes, an end of the world broke unexpectedly over the heads of these thousands of victims. This earthquake was felt throughout the entire northwestern part of Europe, on the British Isles, in Germany, in Switz-

erland and in Southern Scandinavia. In these days when more attention is given to natural phenomena even by those who are not directly the sufferers, earthquakes have not only been noticed by means of sensitive instruments but even felt as perceptible jarrings over a still larger area.

Land Torn up by an Earthquake.

Indeed in the case of the great earthquake of 1895 which had its center in Argentina, the whole globe was perceptibly shaken. In Japan as well as in Italy, its effects were felt. Imagine what power would be required to lift a mountain one thirty-second of an inch. Yet the most ex-

tensive mountain range is small in mass compared with such continental areas many miles thick as are thus set in motion. And when we learn that in the case of the earthquake of 1891 in Japan, a quarter of a million of houses were destroyed, we may well ask whether these awful

Destruction Caused by Storm.

forces might not at some time so shake the whole globe that all the works of man would crumble perhaps in an instant.

In order to answer this question we must inquire into the causes of earthquakes, just as in the case of storms we inquired into their causes. Are there any constant factors at work upon which, at least in the normal course of things,

we can count here also? Unfortunately the same thing is true of our knowledge of earthquakes which we found to be true of volcanoes: in both cases we are still very much in the dark concerning the causes of the phenomena. Only within the last ten years have observations of earthquakes been made systematically and with sufficiently sensitive instruments, so young is the science of "*seismology*" which thus far has accomplished nothing beyond gathering and to some extent sifting a comprehensive collection of observations which will be used in the future as a basis for the construction of scientific theories. For the present however it appears that these most terrific of all natural phenomena are at the same time the least understood. Even in the caprices of the weather we recognize nowadays more law and order than in earthquakes. Still some of the more prominent phases of their make-up are known to us and these afford some substantial clues to a solution of the problem under consideration.

In the first place it is clear that there are definite regions on the earth's surface where earthquakes occur oftener and with greater violence than in others which may be regarded as relatively free from them. For example in the plains

of northern Germany, earthquakes have been observed only very seldom; and when they have occurred, they were found to be the remote effects of larger earthquakes centering outside of this territory. Again, except for Egypt and the coasts of the Mediterranean, nearly all of Africa is free from earthquakes. Territories rich in earthquakes, on the other hand, are usually though not invariably rich in volcanoes. The western coasts of North and South America which are thickly dotted with the great volcanoes of the Andes from Alaska to Tierra del Fuego ("Land of Fire"), are likewise frequently visited with earthquakes. In Central America there is a district where the earth's crust is almost incessantly in motion, so that the natives have called it "the hammock." On the other hand volcanoes as well as earthquakes are rare along the entire Atlantic coasts of the American continents with the exception of the neighborhood of the Allegheny mountains which, however, is not a volcanic district.

It seemed natural to infer therefore that there is some direct connection between earthquakes and volcanic phenomena. For during an eruption, the surrounding country is always shaken more or less; indeed in view of the accompanying ex-

plosions, this could not be otherwise. However it became necessary to change this view to some extent, since it was found that volcanic outbreaks can by no means be the universal cause of earthquakes, but on the contrary, that both phenomena, earthquakes and volcanoes, must have a common underlying cause. We must be careful to distinguish clearly between volcanic earthquakes and those that are neither caused nor accompanied by any volcanic phenomena whatever. The latter are described as "tectonic," that is, upbuilding earthquakes because they help to build up the structure of the earth. Earthquakes of this type are invariably the most extensive and therefore they must be the effect of a far greater force than that which causes volcanic earthquakes. Volcanic earthquakes, it is true, may, in the immediate vicinity of the volcanic explosions, surpass tectonic shocks in violence; but then they are always confined to this vicinity of relatively small area. During the eruption of Santa Maria in Guatemala, October 1902, the earthquakes for a whole day took the form of "one continuous shaking which gave one a sensation similar to that experienced on board a ship in deep sea." (See the author's *Von Saint Pierre bis Karlsbad, Studien über die Entwicklungsgeschichte der Vulkane.* 2 ed. Berlin, 1904, p. 45.)

But only a few miles away from the centre of this terrific eruption there was no evidence of the earthquake. In the fearful catastrophe of St. Pierre, the earthquakes were of subordinate importance. If nevertheless the most sensitive seismographic instruments registered microscopic tremors of the earth's crust even in Potsdam, this is to be accounted for as the effect of a distinctly secondary phenomenon. Earthquakes are often caused by sudden fluctuations of atmospheric pressure resulting from such volcanic explosions. It is common knowledge that the atmosphere represents a considerable weight. Its total pressure upon the earth's crust is equivalent to that of a sea of mercury two and a half feet high, covering the whole globe. It is easy to understand that if, over an area of thousands of square miles, the thickness of half an inch of this mercurial sea should flow off elsewhere, the earth would breathe again and expand under the diminished pressure. It has been observed in stone quarries that strata, after they were relieved from the pressure of the overlying layers, have swelled and formed folds such as are seen in mountain ranges. In this sense there is therefore—what was believed long ago but meantime much disputed—a connection between earth-

quakes and barometric pressure. On old barometers the mark "Earthquakes" is to be found underneath "Storm." And in fact a tendency to earthquakes is to be expected during low barometric pressure.

Another very striking example of a terrific earthquake confined to a small local area is that of Ischia which took place in July and August 1883. After slight tremblings had for several days previously been noticed upon the island there occurred on the 28th of July, a sudden violent shock which transformed the city of Casamicciola into a heap of ruins under which thousands of human beings were buried. Gentle quiverings followed, and then complete rest was restored. Only at infrequent intervals in August and September, the mysterious subterranean force heaved with subsiding energy against the earth's crust, and then it ceased. Ischia is an island between the Bay of Naples and the Gulf of Gaeta, forming a continuation of "the Burning Fields" (Campi Phlegraei) where volcanic activity rages almost more uncannily than under Vesuvius itself. For here eruptions occur at times in wholly unexpected places. Thus in 1538 in the midst of a coastal plain rich in vegetation, there was thrown up suddenly, amid thunder and

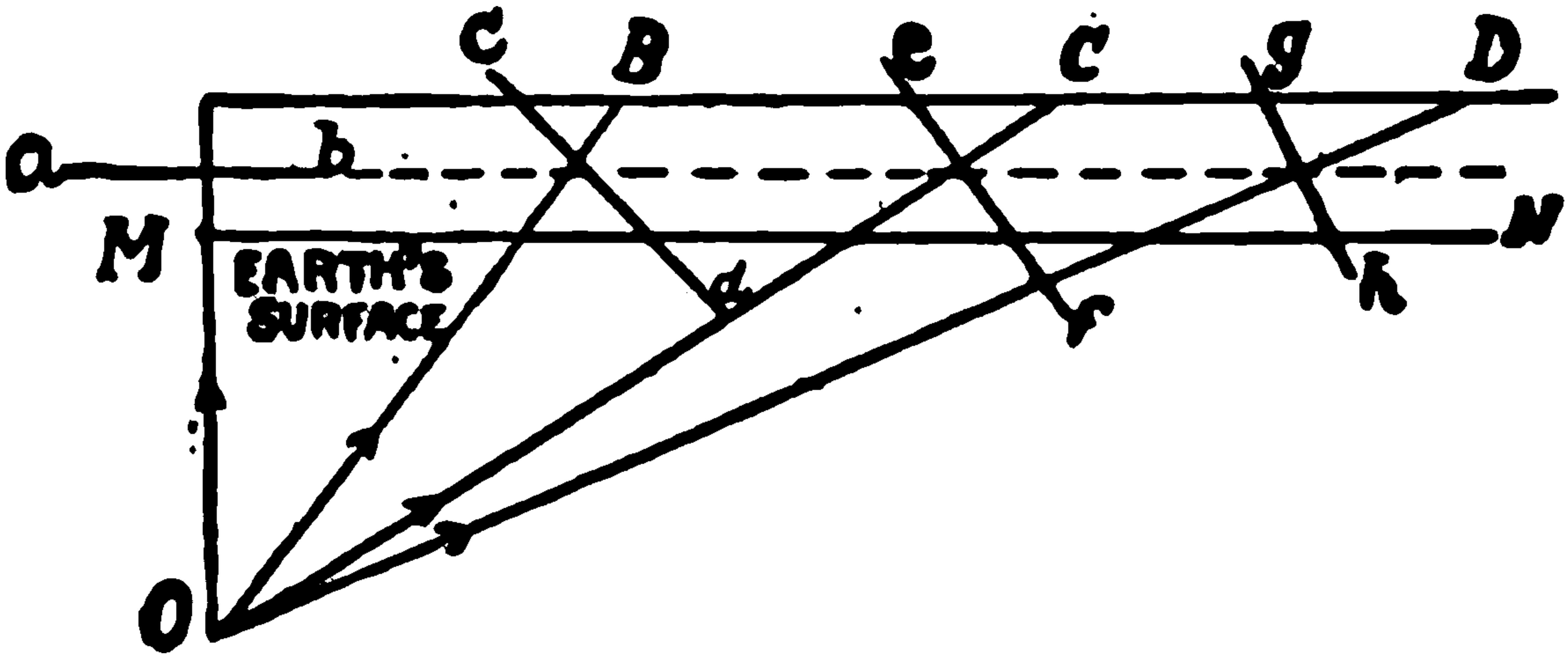
lightning and violent ejections of glowing ashes, a new volcano which has had but this single cruption. In recognition of its recent origin, the hill is named Monte Nuovo, or "the New Mountain." The principal peak on the Island of Ischia is likewise an extinct volcano called Epomeo; it had its last eruption in 1302, when it ejected the lava-stream of the Arso which is barren even to this day. Ever since the volcano has been inactive until in 1881 it again drew attention to itself through an earthquake which was followed two years later by that fateful shock. The volcano itself, it is true, remained inactive; only the lava-streams issuing from the scoria-cones of the vicinity were hotter and flowed more freely, the gaseous vents, or fumaroles, redoubled their activity and there are reports that in some places the earth was found to be much heated a few feet below the surface. We must conclude that at no very great depth the volcanic activity, which had been chained but not subdued, was trying to find a vent by means of an explosion without however this time suceeding in forcing a way to the surface. Such earthquakes have often heralded fatal eruptions. Pompeii, for example, was partially destroyed by earthquakes sixteen years before the famous eruption of Vesuvius in

79 A. D. Moreover at that time Vesuvius must have been considered one of the extinct volcanoes just as Epomeo on the Island of Ischia is today. It is therefore quite possible that that island may yet share the fate of Pompeii and Martinique Island.

The earthquake of Casamicciola, since it was thus caused by volcanic activity even though no eruptions occurred on the surface, was confined to the island. The instruments of the observatory on Vesuvius were not at all affected by it. Indeed throughout the surrounding volcanic districts, no effects whatever were noticed.

Now there is a method by which one can determine approximately the depth of the centre of disturbance. A blow struck upon an elastic body causes it to vibrate just as sound produces vibrations in the air and light in ether. But the earth's crust, composed of rock, is also more or less elastic. Such vibrations spread out from the centre of disturbance in a spherical form. Accordingly when a blow is struck upon the earth's crust from a certain depth, it must, as the accompanying illustration shows, reach the surface the later the farther that particular spot is removed from the one which lies exactly above the centre of disturbance, that is, from the *epicen-*

trum M of the earthquake. If the blow is struck at the point *O* in the earth's interior, the resulting shock at the epicentrum *M* will have a vertical direction lifting objects on the earth's surface so as to strike *ab* at right angles. The farther the point of observation on the earth's surface is removed from the epicentrum, the more oblique will the line of direction of the shock be. For example, at *B* the vibrations will have the



line of direction *OB* falling at right angles on *cd;* at *C*, *OC* falling at right angles on *ef* and so forth. Comparisons between the time and the direction of earthquake vibrations afford the data for determining the location of the actual centre of disturbance.

Whereas in this way the centre of disturbance of the most violent earthquakes has often been located at no great depth, in the case of the earthquake of Ischia for example, certainly not

more than 1,500 feet; on the other hand it has been found that earthquakes which, though they are at times less vehement, extend over larger areas, have reached the surface from a depth of many miles. In one instance the centre of disturbance was located twenty-five miles below the surface. What a terrific force it must have been to shake whole continents at so great a distance. Again we are confronted with the anxious question: Could not such a force some day destroy all that man has labored to upbuild with his hands and with his brain? Is it not possible that the awful convulsions of an earthquake might cause an end of the world as far as man and his works are concerned?

Where do these forces come from? Clearly they are not of terrestrial origin for we know of no force due to conditions on the earth's surface that could produce even approximately such effeets. From the standpoint of cosmic forces however, the movements observed during the most violent earthquakes, are slight indeed. What cosmic force is it then that grips the earth at intervals, shaking it to its foundations? The earth floats unimpeded through empty space in its orbit around the sun; and while, in astronomical parlance, all other planets "disturb" its course, yet even these perturbations cannot be

otherwise than steady and regular in their operation. Sudden impediments in the clockwork movements of a heavenly body are unthinkable. But we have already taken notice of another force to which we attributed even the power of

Fissure at Madori, Japan, caused by the great earthquake of 1891.

causing the explosion of a whole planet; namely, radiation of heat. Although the tension between the earth's crust and its interior is to some extent counteracted by the pliability of all rock strata even of such as are seemingly quite rigid; still

the crust, because it cools faster, must finally become too tight for the planet. Fissures are unavoidable; and these are in fact often produced by earthquakes. The ground gapes suddenly and in its awful jaws is swallowed up what man and nature had built upon that site so firmly, as it seemed, and so securely. Rocks and clods of earth roll after into the yawning grave perhaps of hundreds of human beings. In some districts fissures several yards wide and many miles long have been formed. On the other hand, earthquakes have in some places been known to shove strata together so as to form ridges, and again they have tilted beds of rock or twisted them. It appears then that mighty forces are everywhere pushing and tugging at the earth's crust in order to effect changes in its features corresponding to an equilibrium of the contending forces. The surface may thus be fractured repeatedly while the underlying strata remain perfectly pliable.

But there are other processes besides the cooling of the earth that cause disturbances of its crust. Our planet is constantly contracting not only because of radiation of heat but also on account of its own weight. By this contraction of the earth under the pressure of its mass, much of the radiated heat is replaced. In luminous

bodies like the sun, the generation of heat through contraction is greater than the radiation of heat, considerable as the latter is precisely in the case of these orbs. But after the material of a heavenly body has been, like the earth, much compressed, the generation of heat diminishes constantly. It is certain, however, that our earth has as yet by no means reached its maximum limit of compression. Its average density is about equal to that of iron. Platinum has a density almost three times as great. Now, in a sphere, the pressure increases toward the centre. The centre is therefore compressed more than the surface. Thus the effect produced is exactly opposite to that caused by radiation of heat: the crust becomes too large for the interior. In consequence folds are raised like those of mountain ranges. Now it may happen that lengthwise of such a fold the crust for some reason cannot rise enough. It breaks off. A steep declivity is thus formed on one side of the fold which on the other side rises gradually in a wavy slope from the plain. The Alps are an example of this. They rise very gradually on the north through a series of ridges swelling ever higher; on the Italian side, on the contrary, they fall abruptly to the valley of the Po and, in the west, to the ocean. In former times the

foot of this steep declivity was washed along its entire length by the sea which then covered what are now the lowlands of northern Italy. It is easy to see that, when a part of the crust sinks deep enough down, the sea, since it covers all the deeper lying parts of the earth, must flow in over it. This explains why there are so many precipitous coasts with towering mountains rising in steep ascent from the sea. Of such formation, for example, is the Pacific coast of North and South America upon which the gigantic mountain range of the Andes rears itself imposingly. With but few interruptions it encircles half the globe, extending from Alaska to beyond the south pole; for in the light of recent developments in South-polar explorations, it is almost certain that Victoria Land with its two great volcanoes, Erebus and Terror, constitutes a continuation of the Andes similar in its fundamental characteristics and in its life-history.

There are still other causes that necessitate a slow readjustment of the crust. One of these is the gradual retardation of the earth's rotation on its axis. Marvellously systematized as is the clockwork of the heavens (we shall give more attention to this phase of our subject later on), it does not operate without hindrances which become noticeable after hundreds of thousands of

years. In this respect it fares like the clockwork made by the hands of man. It becomes clogged with dust in the course of years. For indeed relatively a great deal of dust whirls about in space, falling constantly upon the earth and thereby slowly but steadily retarding its motion. It has been observed moreover in the case of other planets that the younger their stage of development, the faster they rotate on their axis. Now in view of the plasticity of the earth, the flattening at its poles must always be exactly proportioned to the centrifugal force which drives the parts of the equator away from the earth's centre and thus has produced this polar flattening. Accordingly since the earth's speed of rotation steadily slackens, the flattening at the poles must be diminishing gradually, so that the earth is becoming more nearly a perfect sphere. There is therefore a constant movement of the earth's mass from the equator to the poles. To be sure this movement is but very slight within epochs of human history, but it is of the same order of magnitude as that due to the process of radiation of heat as described above; and both operate steadily. This slow movement of the equatorial bulge in the direction of the poles can therefore produce tensions which at times result in earthquakes. There is another cause, con-

nected with the earth's axis, which effects disturbances of the crust. It is the fact, known only for about two centuries, that the poles slowly move in spiral path over the earth. With this swing of the poles, the great bulge at the equator three miles in height must move also. Though within the comparatively short period of time in which we have made observations, the poles have moved only a score or so of yards, it is not impossible and indeed probable that these oscillations have been at some time much more considerable. And even today there are evidences that the spiral swing of the poles is increasing.

All these forces evidently lay hold on large areas of the earth's surface at once and therefore the tectonic earthquakes thus caused are found to be the most extensive. It is easy to understand that different parts of the earth's crust have naturally developed different degrees of firmness, some being hard and unyielding, others weaker than the average and so especially subject to fracture. All bodies have weak spots which cannot effectually resist pressure. The earth developed such weak lines where masses of continental extent shoved past each other or over each other, or where one side sank while the other remained standing. Now since we have seen on the one hand that all forces that pro-

duce extensive earthquakes act steadily and very slowly, and on the other hand that the crust is by no means indefinitely unyielding, it is clearly impossible that the tensions and pressures which ultimately find vent in earthquakes should grow to unlimited proportions. *The catastrophes which are to be feared from earthquakes must also have their maximum limit just as those arising from disturbances of the atmosphere.*

We are now confronted with the question as to how far this maximum can exceed seismic catastrophes of which we have knowledge. A mere rough estimate will not however suffice to dispose of this question. That these forces have in the course of time produced great changes in the features of the earth, is proved by our mountain ranges. Along the western slope of the Andes, a piece of the earth's crust as large as the Pacific Ocean has sunk several miles. If this took place suddenly it was a catastrophe of terrific proportions. On the Pacific coast of Asia, the indications again are that the bed of the sea was formed by the subsidence of dry land; and in fact this process is still going on. We may assume that the floor of the entire Pacific Ocean was at one time dry land and that thus an area of land larger than all our continents combined sank so deep that the sea, which at that time

covered other regions of the earth, flowed in over it. It may be that previous to this catastrophe all that is now land was sea so that there has been an interchange of the boundaries of land life and ocean life. In any case it is a fact that all the parts of the earth's crust which today offer a habitat for land life, were at one time sea bottom with the exception only of a few islands that rose above the primordial sea. The rock-beds of what is now dry land prove this. They are of sedimentary formation, being the hardened deposits of sea ooze in which are found embedded the fossils of sea animals. Such an interchange of land and sea, provided it occurred suddenly, must have caused the destruction of all living things.

Let us now consider more in detail the process by which a new ocean is formed through the sinking of a continent. We shall find this worth our while because it will throw light on several interesting points.

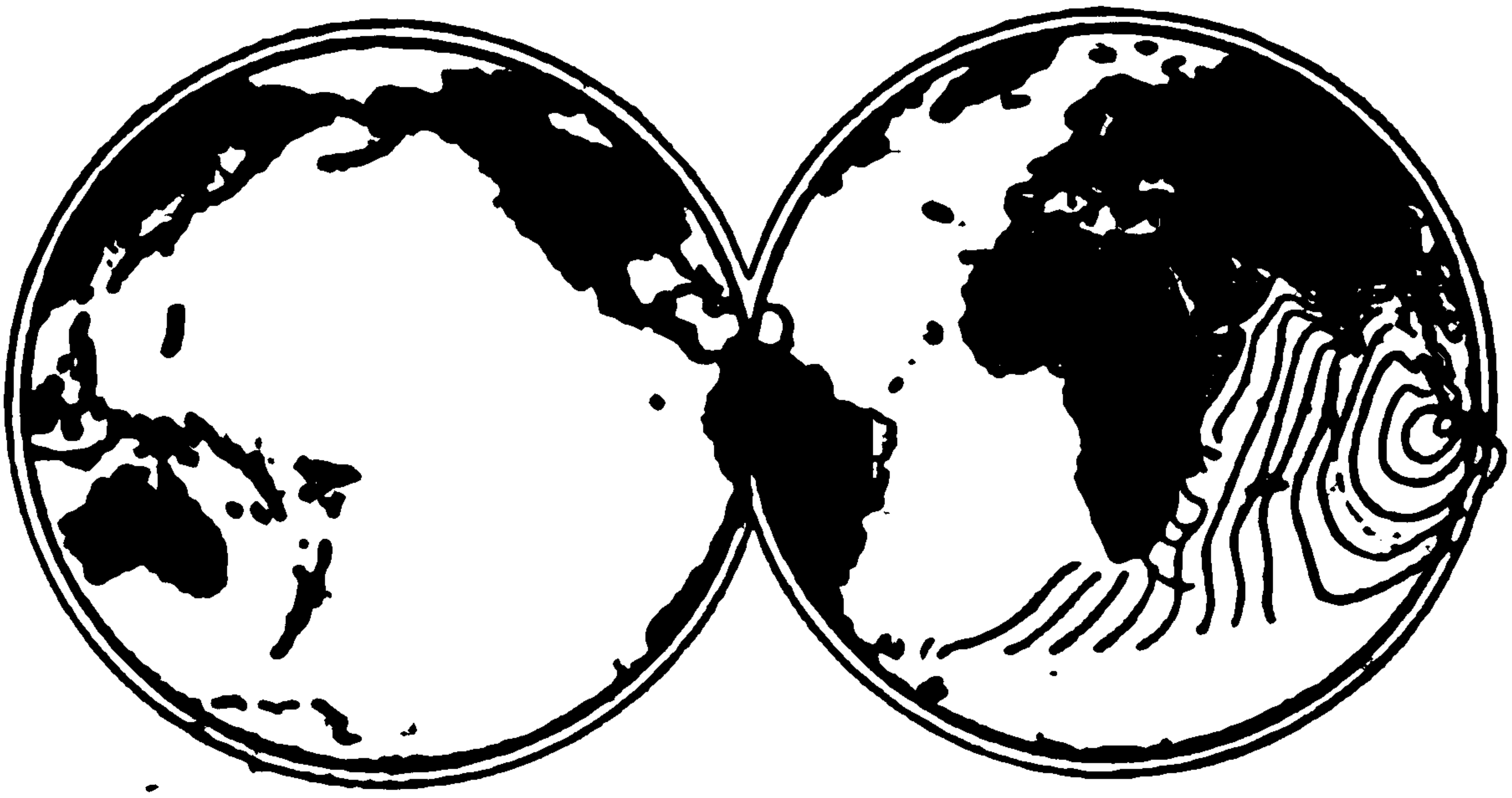
The peaks of the Andes rise to the height of over 20,000 feet and near their base the floor of the ocean lies at an even greater depth below sea level than that giant mountain range towers above it. What is now the bed of the Pacific Ocean has thus reached its present level by sink-

ing a depth of over 7 miles. Now the temperature of the earth rises on an average about 1 degree Fahrenheit for every 60 feet of descent below the earth's surface. At a depth of 7 miles the rise of temperature would therefore amount to about 600 degrees. At this temperature many metals begin at least to soften. In case then a part of the earth's crust should sink abruptly to such a depth, the rock exposed at the bottom would be soft and could not withstand the pressure which during such occurrences moves continental masses. It would overflow along the line of rupture and ultimately it would, at least in some places, form an outlet to the surface for the deeper-lying sea of fiery molten matter called *magma*. But that is equivalent to saying that volcanoes must be formed upon these lines of rupture. And this has in fact happened. Along the entire length of the Andes, from the Arctic regions to the south pole, volcanoes have been formed upon mountain ridges which are not themselves of volcanic origin. Because these volcanoes are set upon the gigantic pedestal of the Andes, their height above sea level is no indication of their significance as volcanoes. To illustrate, Etna which is only 10,800 feet high, is a more important volcano than almost any of the

volcanoes of the Andes although these have heights of over 20,000 feet from which, however, 14,000 feet must in many cases be deducted as a non-volcanic foundation, whereas Etna has upbuilt itself from sea level with its own products. The formation of volcanoes upon ruptures explains their distribution in lines which is noticeable not only in the case of the volcanoes of the Andes but indeed in all the larger volcanic districts. In all these places there must have been, in correspondence with our theory, lines of rupture which the magma streaming forth from the breach filled up, just as a wound is closed by the clotting of the blood that flows from it. A great ring of volcanoes encircles the whole Pacific Ocean and thus this entire ocean basin is, as we have already surmised, a submerged continent.

Now we understand, too, the connection between volcanic phenomena and earthquakes. The latter are, in their aspect of tectonic widespread convulsions, the primary phenomena. Mighty forces are still tugging and pushing at the weak parts of the crust where it has already been ruptured. At times an old wound is torn open again. The shifting about of masses in the earth's interior may also cause a sudden lessening of pres-

sure somewhere so that rock masses formerly kept in a solid state by compression become fluid or even gaseous, and violent volcanic explosions result. We see therefore that volcanic outbreaks are always only the results, never the causes, of extensive earthquakes. Not many decades ago



Map of the earth showing distribution of volcanoes along lines. The position from hour to hour of the sea wave caused by the explosion of Krakatoa is indicated by curved lines grouped around the volcano. The last bit of curve touching the extremity of South America shows accordingly that the sea wave arrived there with perceptible force seventeen hours after the explosion. The dotted line enclosing the center of disturbance indicates the region over which the sound of the explosion was heard.

the reverse was usually believed. Every earthquake was viewed as the consequence of some volcanic activity and, when there were no accompanying volcanic displays, it was assumed that the eruption must have been subterranean. The new view here expounded explains also why tec-

tonic earthquakes occur most frequently in volcanic districts without, however, being confined to them. For the forces that shake the earth's crust, take hold of it where it is weakest, that is, where ruptures have already been formed; but this does not prevent whole continents from being convulsed at times when the forces operating are unusually violent. One can understand too that in certain regions earthquakes can continue without interruption for several years, for the reason that the rock masses yield step by step to the pressure brought to bear upon them. The earthquake which has become most famous, or rather, most notorious in this respect, is that which took place in the Greek province of Phocis where for three years from 1870 to 1873, the convulsions continued without interruption accompanied by underground thunder and landslides. There were days when, in round numbers, 29,000 separate shocks occurred or on the average one shock every three seconds. Very violent destructive shocks alternated at irregular intervals with lighter ones. The unfortunate population, already poor before this visitation, was thrown into such a state of constant nerve-racking terror that insanity and epilepsy became epidemic. Then the outbreak subsided as it had

begun. Aside from the fact that there are no volcanoes in that district, we do not know of any example of an eruption that could account for the long duration and the irregular appearance of those earthquakes. More recently, in the winter and spring of 1903, similar long-continued, though in this case not very violent, earthquakes occurred, as they had once before, in the Vogtland, that is in the neighborhood of the rupture upon which the hot springs of the Erzgebirge are still to be found as remnants of a subsiding volcanic activity. These hot springs, however, underwent no changes that could have been interpreted as signs of a reviving volcanic activity underground. The tectonic forces here operating shook a part of the earth's crust so large that it connects Germany with the Antilles. For a fuller treatment of this subject the reader is referred to the author's book quoted on page 39.

When a broken block of the earth's crust sinks to such a depth, the catastrophe does not end with the ejection of lava from the fracture and the formation of volcanoes with occasional accompaning explosions. As the sea floods the submerged land, a mighty conflict ensues between it and the fiery magma that breaks forth out of the depths. Along the whole rupture

catastrophes like that of Krakatoa become the order of the day. The sun is darkened. Great masses of water and of dust are constantly whirled into the air. When that single volcano sank in a similar way beneath the sea, the effects of the volcanic products that had been blown into the air were observed for many years after. In this case, however, we are concerned with occurrences which took place along a line of rupture reaching half around the earth where volcanic activity must certainly have raged with inconceivable violence for thousands of years. There can be no doubt but that in the inflowing parts of the sea all living things must have perished, and while it is not likely that the destruction caused directly by the eruptions—thousands of which perhaps broke out here at the same time—involved all the existing dry land, still the weather conditions which followed must have had fearful effects. The air was filled more and more with moisture causing an increase in rainfall especially as the great mantle of dust which had spread through the atmosphere intercepted the sunlight and so diminished considerably the amount of heat received by the earth. Now the warmer the air is the more moisture it can retain in the form of vapor. The increased rains and

the constantly clouded sky kept the sun's heat always more from the earth. The result was that the tendency of the whole circulation of water in the air was downward. A complete change of climate had to ensue over the whole earth. After the deluging rains subsided, the earth remained damp and cold. Glaciers slid from the mountains lower and lower down into the valleys, for the sun could not melt the great masses of snow that fell continually upon the summits. Thus even districts where otherwise the temperature in summer would have been above 32 degrees Fahrenheit, were permanently sheeted with ice just as the ends of the Alpine glaciers to this day descend below the limit of continual snow. Finally even the plains at the foot of the mountains were covered over large areas with an ice-sheet that grew thicker and thicker. The ice age, or glacial period as it is called, set in, the effects of which can be seen even now over the whole earth. It was the merit of Professor Hans Meyer of Leipsic to have demonstrated by the evidence of Mt. Kilimanjaro and, more recently, by that of the Cordilleras of South America, that everywhere even in the tropics the glaciers of that period reached far lower down than at present. The brothers

An inland ice-sheet in Greenland, giving an idea of the ice age. See page 61.

Sarasin of Basel were the first to develop the theory here advanced, that the ice age was the consequence of a period of extraordinary volcanic activity.

This theory is supported by the following facts which have been well established by careful scientific investigation. The Andes mountain range, according to geological reckoning which to be sure measures by hundreds of thousands and by millions of years, was formed simultaneously throughout its entire length. Moreover its volcanoes were developed as a consequence of the process of upbuilding this most imposing of all our mountain ranges. About that time an almost tropical climate prevailed over nearly the whole earth, followed by an enormous fall of the temperature. Penck, at present the foremost investigator in this field, holds that there have been at least four great glacial periods separated by warmer periods. But it appears that these great glacial periods may in turn be divided into a larger number of smaller epochs marking slighter fluctuations of temperature. We see then through what vicissitudes of weather the earth has passed. The length of the ice age can be stated only approximately. According to the most reliable calculations, it must have begun

about half a million years ago. The last smaller glacial epoch dates back perhaps no more than ten or twenty thousand years. Even today we are probably living in one of the interglacial periods, such as occurred before the last glacial epoch spread its great ice-sheet over the earth. Straight through these glacial periods traces have been found of human beings evolving from an animal origin. The deluge-myths which have come down to us from early ages may have some connection with the vicissitudes described above. The Persian myth points almost unmistakably to volcanic outbreaks as the cause of the great flood. With your leave, I shall here repeat an apposite passage from my work entitled "Die Entstehung der Erde" (5th ed. 1904, p. 367ff.). The Persian myth describes the great flood as follows: "From the south there came up a huge fiery dragon. It laid waste everything. Day was transformed into night. The stars were hid by its gigantic tail which spread over the sky leaving only the sun and the moon visible. Boiling hot water poured down from above burning trees to their very roots. Amid frequent lightning raindrops fell as large as a man's head. Water covered the earth above the height of a man. Finally after the battle with the dragon had lasted ninety days

and ninety nights, the terrible antagonist was vanquished. A great storm came up. The flood subsided and the dragon sank into the depths of the earth." According to the opinion of the noted geologist Suess of Vienna, this dragon was nothing other than a volcano in eruption which spread its fire-streamer like a tail over the sky. All the other phenomena described in this myth tally exactly with those following after a great volcanic eruption.

Thus on the one hand we have shown that after the breaking off and sinking of a huge block of the earth's crust volcanic eruptions must take place along the line of fissure followed by deluges and glacial periods. On the other hand we see before our eyes the great line of volcanoes in the Andes situated close to the Pacific coast with its steep slope to the deep ocean floor; and we know that shortly after the formation of that line of volcanoes glacial periods occurred. Mythical accounts of deluges further fill out the picture of that eventful age in the life-history of our planet. The eruption of Krakatoa affords an illustration on a small scale of all these effects of the sinking of a volcano under the sea. Putting all these facts together, we must conclude that there was actually such a

succession of events as our theory assumed, namely, that the Pacific Ocean throughout its entire extent was formed by the breaking off and the sinking of its present bottom which before had been an enormous continent.

Did this involve a destruction of the earth in our sense of the term? If that continent sank suddenly, the catastrophe must certainly have been the most terrible and the most extensive that the earth has ever witnessed since life first dawned upon it. To answer this question is indeed not an easy matter. But this much we can say: If the sinking had taken place only very gradually, we should be at a loss to explain what it was that, toward the end of the so-called "Tertiary period," brought forth along the entire length of the Andes that tremendous volcanic activity of which the eruptions that to this day still occur there, are but the faint after-effects. If, for instance, the coastal region had subsided as slowly as some coasts do at present where it takes centuries to produce any noticeable effect, then the earth's interior could have accommodated itself thereto as slowly, and only isolated outbreaks would have occurred. To be sure we have seen that these forces that move great earth masses, encounter resistances; else sudden earth-

quake shocks would not occur. But we know also that the tension caused by such resistances cannot exceed a certain limit because the earth's crust proves to be pliable under the influence of forces which, though powerful, operate slowly. All these considerations lead to the conclusion, however much we may wish to avoid it, that a *sudden force* must have interfered here.

We need here to take cosmic forces into account. Whereas even very rigid substances prove to be pliable for slowly operating forces, on the other hand even pliant material breaks under the impact of a sudden blow. Thus we cannot avoid the conclusion that a sudden powerful blow must once have split open the earth from pole to pole. And this naturally recalls the example of the moon's radial system of streamers where the points of impact can be clearly seen as great depressions in the moon's crust. We must not neglect however to say here that there are a considerable number of distinguished scientists who believe that they can account for these radial systems of streamers together with all the formations upon the moon's surface resembling our volcanoes, as the products of purely volcanic activity, in other words, as effects of forces pushing outward from the moon's interior.

There are sunken areas on the moon's surface proportionately as large as our own Pacific Ocean. But I think there is no need of here going deeper into this conflict of opinions since for present purposes it matters little whether those forces, which are able to crack an orb in the way we see exemplified on the moon and again in the Andes mountain range of our own planet, came from within the orb or from outer space. Whatever has been said on the subject thus far makes the former alternative seem at least improbable. We shall now give our attention to the consideration of the cosmic forces that might bring about such catastrophes.

In this connection comets have been from time immemorial an object of apprehension. It is easy to see why. The stars appeared to be fixed immovably upon the firm canopy of heaven. The sun followed unswervingly year after year the same path. Mankind had already of old time learned to compute its orbit as well as those of the moon and planets; and never was there a deviation of even a hair's breadth from the appointed course. It was clear that none of these orbs could ever collide with the earth unless indeed the whole firmament should be thrown into chaos and all order should depart out of the

THE END OF THE WORLD

The great comet of 1843. See page 67.

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world. But the comets came no-one knew whence, and they went no-one knew whither. Their path among the stars seemed utterly without law or regulation. Sometimes in the course of a few days they approached so fearfully near that it was easy to imagine that they were on the point of dashing down upon the earth. And withal their form was so extraordinary that that of itself might well arouse terror. The tail which sometimes extended from horizon to horizon across the whole sky presented a weird appearance, for, brightly luminous as it was, the stars could be seen shining through it as through some transparent ghostly thing—as through an "astral body" one might say with our modern theosophists. What wonder then that, in the times when astrology flourished, comets were considered omens of ill luck, predicting such evils as war, epidemics, famine, drought, the deaths of great men and what not. As long as nothing whatever was known about the nature of comets there was nothing to prevent one's attributing to them all manner of calamities.

About two hundred years ago Newton derived the laws governing the movements of all beavenly bodies from the one principle of gravitation, or the mutual attraction of bodies. It was

only then that the discovery was made that comets, too, are subject to the same laws and accordingly revolve around the sun in elliptical orbits. Though this discovery had been vaguely anticipated before, the prevailing view up to that time was that comets were of "sublunary" origin, perhaps some inflammable evaporations from the earth which might escape through volcanoes. But now it was demonstrated that they came from interstellar space, and some knowledge was also gained concerning their make-up. A vast assemblage of fears was therewith dispelled. The orbits of comets were computed and it was found that these heavenly bodies always kept at a greater distance from the earth than the moon, though they approached nearer than any planet. It was apparent that from such distances they could not exert the slightest influence upon the earth.

But a new fear supplanted those which had been dispelled, and this new one could boast a scientific basis. It was found that the orbits of comets crossed the orbits of the planets including the earth in all imaginable directions, whereas the orbits of all bodies in the solar system heretofore known were inclosed one within the other at such great distances that

they could not meet under any conditions. (The exceptions among the number of smaller planets will be discussed later.) The orbits of comets approached perilously near those of a number of planets, in several instances indeed nearly crossing these, so that, if in their courses the comet and the planet should happen to arrive at the point of intersection at the same time, a collision would be unavoidable, the consequences of which might under certain conditions prove calamitous. Thus the earth's orbit has, at a place which our planet passes every November, a point in common with the orbit of Biela's comet. Now whereas the mass of comets numbering many thousands visit the earth but once, as far as we know never to return, Biela's comet belongs to the score or so of periodic comets which return regularly at short known intervals, this particular one every six and a half years. Once in every revolution, that is once every six and a half years, Biela's comet crosses the earth's orbit. If this should ever happen toward the end of November, the earth would then be at the same place and a collision would be inevitable. Now if the comet is composed of large solid masses, these could, in dashing down upon the earth, produce such violent and long-continued commotion

that one would have to call such a catastrophe a destruction of the earth. Imagine such a bombardment of huge rock masses several miles in diameter, which rush through the atmosphere raising their own temperature as well as that of the air by friction to burning heat, and sending fiery whirlwinds to sweep with furious velocity over the earth destroying everything in their path. As these cosmic bombs fell into the sea they would produce an enormous tidal wave that would pour out over all the continents great deluges which nothing could withstand. Or if they dashed upon some continent, the heat produced by the impact would melt the earth's crust in the vicinity, opening up an enormous passage to the molten interior. A volcano with a crater several miles in diameter would result. Not being able to withstand so sudden a shock, the earth's crust would crack open in fissures radiating from the new crater in the way we saw exemplified on the moon, and upon these fissures whole rows of further volcanoes would be formed. In short, that very catastrophe would have taken place which seems to be recorded by the annals of geology in the Tertiary period.

The question under discussion is coming to a head. The possibility of a collision between a

comet and the earth has been demonstrated, indeed we shall shortly see that such a collision actually occurred not very long ago. Moreover, we can compute with mathematical accuracy the enormous velocity with which in a given case these bodies would have to collide. All that remains to be seen is whether comets are composed of large enough solid masses to produce far-reaching destructive effects.

It is not an easy matter to dispose of this question. The mere appearance of many comets (though to be sure one should never judge by appearances) is indeed terrific enough to lead one to believe that the worst might be expected from such a collision. However in the first place we must leave the enormous tail of the comet out of consideration. We know by accurate computation that the diameter of the earth could be contained several times in a cross-section of a comet's tail. And yet the light of the stars shines through this tail with undiminished brilliancy as if through vacant space. In contrast with this, our own atmosphere for example perceptibly diminishes the brightness of the stars, as we know from the fact that they fade gradually as they near the horizon. We conclude that the tail of a comet must be com-

posed of highly rarified matter like that which is to be found in our Roentgen tubes where the so-called cathode rays display their wonders, and very likely the light emanating from a comet's tail is of the same nature or of the nature of radium. The comet's tail therefore can do no mischief. An appearance of greater solidity is, however, presented by the comet's "head," as it is called, from which the tail issues. By far the most of the comets, including nearly all the smaller ones, have nothing but the head or they develop only an exceedingly small tail, always extending in the direction away from the sun. This head usually looks like a small dissolving luminous cloud, which, as far as our observations extend, never attains large dimensions even in the case of comets having large tails. It is true that there have come down to us from earlier centuries drawings of comets with enormous round heads in which there was supposed to be a furious turmoil of whirling masses; but we do not know how far the terror with which these heavenly bodies were regarded may have led to exaggeration in those days. Usually, though not always, there is a brighter spot in the center of the head which sometimes even looks like a clear, brilliant star: the so-called nucleus.

This nucleus often gives decidedly the impression of a solid mass which might prove formidable. At first, while the comet is approaching the center of the solar system, vaporous emanations stream forward from the nucleus in the direction of the sun; it is only when the electrical repulsion of the sun begins to take effect that the vaporous streamer swings backward in a great curve behind the head so as to form the tail. We can analyze these vaporous emanations by means of a spectroscope. Their constituents are found to be hydrocarbons, such as constitute our petroleum, sodium which is contained in ordinary table salt, and also vapor of iron, though the last-named element occurs less frequently. During the thousands of years of travel through empty space, all these vapors would have escaped into the void if the comet as a whole were also gaseous instead of having a solid nucleus which through its gravitation could hold fast these vapors either as an atmosphere or in a more compact form. The nucleus of a comet *must* therefore have some solidity.

It remains to be seen how formidable this more or less solid nucleus really is. There is a method by which one can determine the weight of a heavenly body as surely as if it could be

placed on a balance. In this way the earth itself and the sun, Mars and the other planets have all been weighed. The method is absolutely reliable. But when a comet was placed in the scale of this cosmic balance, the index did not budge. There seemed to be nothing whatever in the scale. In this respect the cosmic balance is like an ordinary one. It is not to be expected that an apparatus designed for weighing whole wagon-loads can be used also for weighing gold. Even a few million tons would be as nothing for this cosmic balance. Thus a weight which from our standpoint is truly enormous, becomes from the cosmic standpoint a negligible quantity. And so we do not feel reassured as yet regarding the formidable character of comets. What further available knowledge is there on the subject?

I said before that our planet once collided with a comet. This happened on November 27, 1872. I myself witnessed the collision from the observatory at Göttingen, where I was at the time a first semester student. It is true I had no idea of what I was actually seeing. But it was the most spectacular display of celestial fireworks that it has ever been my fortune to behold: a magnificent meteoric shower. Fire-balls rained from heaven; often in a single second

several glanced silently in majestic curves past the unchangeable constellations. If one drew their paths on a map and produced these backward, it became evident that they had all come from the same point in space situated in the constellation of Andromeda. Klinkerfues, who was then my director, showed me how to compute the orbit of the meteoric swarm from knowing the location of the "radiant," as the point from which the shower comes is called. I spent the whole night figuring and, when by morning I had at last succeeded in getting the orbit, I went with it to my director, whom I found taking breakfast. He smiled with satisfaction as he saw my results and said that I had figured correctly, that he had just also worked out the problem at breakfast. He told me further that it was Biela's Comet, the comet which had been missing so long, that had surprised us with this splendid display of fireworks and that it could probably still be seen on the opposite side from which it had come. This part of the heavens was not visible where we were. Klinkerfues therefore telegraphed to Madras, where a comet-like body was actually observed in the spot designated. For a long time the correctness of these computations and of the conclusions based upon

them was questioned; and in fact on account of certain deficiencies in the observations they were not wholly proof against attack. When, however, the same magnificent display was repeated after exactly thirteen years, on November 27, 1885, those conclusions became unassailable. This period of thirteen years constitutes two revolutions of the comet, which accordingly had to be at the same place on this day of the year as in 1872, whereas after the elapse of only six and a half years it had to cross the point of intersection a half year before our earth. Only after complete revolutions of both heavenly bodies can they meet again in the same spot in space.

Biela's Comet, it has been seen, consists of shooting stars. Can shooting stars do any mischief? Fortunately for us, they cannot. It can be demonstrated that even very bright shooting stars need weigh only a small fraction of an ounce. Because of the cosmic velocity with which they penetrate our atmosphere they are so heated through friction that they not only become incandescent but are instantaneously consumed. Often they disappear thus at a height of one hundred miles above the earth's surface, and it happens only rarely that a shooting star

reaches lower than an elevation of fifty miles before it dissolves into a small cloud of vapor and vanishes into the air. A comet might, therefore, pelt the earth with a thick hail of shooting stars without so much as killing a fly. It is precisely their enormous velocity, which is at least ten times as great as that of our best firearms, that secures for us perfect protection against them; for this it is that causes them to be consumed. Our earth is well guarded against danger from this source by its atmosphere, which presents a more impenetrable covering than the strongest steel armor of a man-of-war.

But are all comets composed entirely of such shooting stars? Is there any way of knowing? There is but one other known comet that crosses the earth's orbit and which might, therefore, be tested in the same way as Biela's Comet has been. This other comet has in fact also yielded us splendid meteoric showers, the Leonids, as they are called, which have been observed regularly each year in the second week of November and which make their appearance in exceptionally large swarms every thirty-three or thirty-four years, the period namely of the comet. However, both these comets are very small bodies of cloud-like aspect with scarcely per-

ceptible nuclei. Besides we do not know whether we have ever experienced a collision at the very point of intersection of the orbits, that is, whether we actually passed through the nuclei of these comets. Moreover, it is certainly not to be assumed that the nuclei of the larger comets consist merely of somewhat denser clouds of shooting stars; larger solid masses must of necessity be contained in these.

Does our atmosphere offer protection against the entrance of such larger bodies? To a certain extent it does. It is by no means an unusual thing for our atmosphere to be invaded by balls of fire from which red hot rocks, weighing a hundred pounds or so, fall down upon the earth with a terrific thundering sound. Even in the case of these larger intruders the atmosphere diminishes at least their cosmic velocity; when they are still at an elevation of more than sixty miles they are retarded in their descent. The heat generated by friction consumes, however, only a small portion of their mass; the rest dashes down upon the earth, though only as if its descent began at the point of retardation, in other words, with no very remarkable degree of velocity. Usually the meteorite (for so the fireball is called) explodes in mid-air and falls to

the earth in fragments. The reason for this is that the body coming from icy space, where a temperature of about 400 degrees below zero prevails, has its temperature raised suddenly about 2,000 degrees,' so that it bursts just as glass does if heated too quickly. When the fragments reach the earth they have an enamel coating pitted over with hollows that was formed by the fusion of the crust. From earlier times there have come down to us many accounts of how great damage was done by such stones falling, or even raining down, out of a clear sky. There are stories to the effect that whole villages were thus set on fire and that flocks peacefully grazing were thus killed. There is, however, only one well-authenticated case where a human being was killed by a meteorite. But recently, in December, 1903, a ship came near being sunk by one on the open sea, in the Bay of Biscay. During a storm, which had suddenly broken forth there in December, when they are very rare, the masts were struck by lightning, and a few minutes later a great mass fell with a peculiar rushing sound into the sea close by the ship, so that the waves dashed to an enormous height.

All these stones which have fallen from the sky, although they contain no new elements

which are not found upon the earth, have a characteristic formation. It is by this formation—though unfortunately I cannot here go into the details of the matter—that we can know meteoric stones even when they do not fall from heaven before our eyes. The largest that was actually seen falling weighs 715 pounds; it fell in Finland on March 12, 1899. But stones that are unquestionably meteoric have been found weighing a hundred times as much. The fall of such a mass of stone weighing thirty to forty tons would suffice to shake the earth's surface violently over a large area; and it is by no means impossible that, among the earthquakes which sensitive instruments often register over large districts, there is one here and there which was caused by a meteorite that, unseen and undiscovered by us, fell in some unknown region of the earth.

Observation teaches that in the heavens, too, things occur oftener on a small scale than on a large scale. Millions of shooting stars fall every night, and almost every day a larger meteoric stone falls from the sky, although scarcely one in a hundred is noticed. There is no fact of science to contradict the view that it would take only a correspondingly long period of time for

Portion of the moon's surface pitted with craters (Theophilus). See page 82.

a meteorite of the magnitude of a heavenly body to dash against the earth. And so it is easy to see that the protective power of the atmosphere must have a limit. The smaller bodies coming from space are consumed in the air; those somewhat larger are retarded in their excessively swift descent and broken into pieces; but when the intruders become so large that their diameters measure several miles, the atmospheric resistance is not powerful enough to check their velocity, just as in the case of a falling cannon ball in contrast with a feather. The orb-like meteorite crashes with cosmic velocity against the earth's surface; its energy is so largely transformed into heat by the shock that much of the huge mass of rock melts and fuses with the lava streams that gush from the newly formed crater out of the earth's interior. At the first most violent impact much solid matter was at once converted into gas, which, by explosive expansion in conjunction with volcanic eruptions, blows up a portion of the fallen mass, flinging it in part perhaps back into space whence it came. Other fragments fly down again in great curved paths, and, as they scatter around the enormous new crater, the same phenomena are repeated on a smaller scale which took place at the first

impact. Thus smaller craters are formed round about the largest one, and these, therefore, are not found distributed in rows like those that are formed upon volcanic fissures.

Now this very thing which we have thus shown to be theoretically possible has, as we can plainly see, actually taken place on the moon. Our satellite was visited with catastrophes more frequently because it lacks the protective covering of an atmosphere. Cosmic projectiles reach its surface with undiminished force. They have driven hollows hundreds of miles in diameter into the moon's solid crust. We have already discussed the radial clefts, produced under these circumstances, which were immediately filled up again either by lava issuing from the interior or by the molten mass of the projectile itself. Moreover we see the moon's larger craters surrounded by hundreds of smaller holes, which look exactly like hollows made by rain-drops in soft clay and which, as far as we can tell by observations made from the earth, are rounded pits and not, like the larger central ones, genuine craters having a flat bottom and a steep wall. In view of all these facts it seems to me there can be no doubt but that the conformations of the moon's crust described above were produced by the im-

pact of bodies coming from outer space and not by processes at work within the moon's interior. Thus the consequences of catastrophes involving the destruction of an orb are plainly visible on the heavenly body nearest our planet. The same thing not only may but must happen to the earth itself. It is merely a question of time.

We have thus discovered what it is that causes such a catastrophic destruction of a heavenly body as, for example, might break any instant over our earth without so much as a few minutes' warning. A body seven miles in diameter looks, even at a distance of 3,000 miles, only about a fourth as large as the moon and certainly its appearance would not at once frighten us excessively. Yet in less than a minute it could have crashed down upon the earth, destroying in the space of a few hours all order there for hundreds of thousands of years. We are, therefore, intensely interested to know more about these meteorites.

Recalling that shooting stars are fragments of comets, we naturally ask whether these balls of fire that so suddenly flare up in the sky have likewise some such connection with comets. They have not. There is no connection whatever between meteorites and comets. During so-

called "meteoric" showers actual meteorites are rarely met with. It has often been possible to compute the path of a meteorite very accurately, and never has any correspondence with a cometary orbit been noticed. Moreover, most of the paths of meteorites have a peculiarity which proves that these intruders upon our earth come from far more remote depths of space than the majority of comets.

And yet comets, too, come from great distances. As our discussion progresses further we shall find ourselves deeply interested in learning more definitely the whereabouts of these beavenly bodies which emerge for a short time into our view as they fly past us. It is important to know something of the origin of these bodies which come so menacingly near us.

We know that the earth is, in round numbers, 90,000,000 miles distant from the sun and that Neptune, the outermost planet, is about thirty times as distant. All the planets revolve around the sun in fixed orbits and all move in the same direction. Their orbits are nearly circular and, with but slight deviations, they lie in one and the same plane, so that the space around the sun in which the planets travel may be compared in shape to a flat lens. This arrangement of it-

self is sufficient proof that the sun and the planets must have a common origin. The case is different with the comets. They come from all imaginable directions and from all conceivable distances far beyond Neptune's orbit. Until very recently, therefore, the view obtained that they did not belong at all to our solar system, that they were lost bodies which wandered without end or aim through interstellar space; if they happened to approach too near a sun they were attracted in accordance with the law of gravitation and so fell toward it. Thus it was supposed that very many comets probably flew headlong into our own sun. It is true that we have never actually seen this happen, but it was demonstrated mathematically that such comets flying straight to the sun would scarcely ever be in a position where they would be visible from the earth. The fact that most comets fly past the sun and not into it was accounted for by assuming that before they come within the range of the sun's attraction they usually have already a slightly sidewise motion through which they are sent with accelerating velocity past the sun which then turns them about and flings them back into space whence they came. However, from the velocity with which they fly around the

sun one can compute accurately the original velocity with which they entered the sphere of the sun's attraction, and this velocity in by far the most cases has been found to be exactly zero. Comets, therefore, stand still on the border of the sun's attraction, whether they are on the point of moving toward the sun or whether they have just returned from it; here they turn about and thus oscillate to and fro in parabolic orbits or in elongated elliptical ones during periods which doubtless are to be counted in many thousands of years. Only in rare cases is it possible to compute these periods even approximately. Comets thus never really leave the solar system, and they must have belonged to it from the beginning, even though only very loosely. They are to be regarded as remnants of the primordial matter out of which the rest of our solar system was formed. The story of how this probably happened will be told by the writer in another volume of this series, which will be entitled "The Making of the World." The end and the beginning of the world are two extremes that touch each other.

The case is different with meteorites. Their orbits often show a considerable initial velocity, which proves that they have really been hurled

from other systems into our own solar system. Strange, that these meteoric stones, fragments of which we can actually hold in our hands, should come from those secret depths of the universe that are far more unfathomable than the inaccessible sister-planets of our globe, and should bring us from those uttermost depths no unknown substances. Nothing could furnish more convincing proof of the unity of the universe.

Since meteorites thus come from outside our solar system, we can learn nothing of their whereabouts which might reveal the extent of their menace. We do not know whether there is a maximum limit to their size and velocity and we cannot tell whether there is anything which might avail to protect the earth against a catastrophic collision with such a fire-ball in case it assumed the magnitude of a heavenly body. Besides, as before stated, we have no means of predicting such catastrophes.

In the case of comets the outlook is brighter. Even the smaller ones are visible while they are still several millions of miles distant from the earth. By observing the apparent path of a comet for but three successive days, its true path through space can be easily computed. Thus it

can be predicted where the comet will be found in the following weeks and months and consequently whether it will cross the earth's orbit. Since comets have all space in which to range freely, such a coincidence is about as likely as that, for example, among a thousand bullets shot at random in all directions one should cut a thread stretched somewhere within range. If the shooting went on year after year, such instances might be met with occasionally; and we have already seen that a few cometary orbits actually cross the earth's orbit. But that a collision should take place something still more improbable must happen. We should have to imagine further in the example given above that bullets were shot lengthwise of the thread and that these would be accidentally hit by the other bullets that were being discharged at random. So exceedingly small is the chance of a collision between the earth and a comet.

To be sure we know that it happened once nevertheless. But we must remember, on the other hand, that the comet in question was one of the smaller ones such as are far more numerous than those of considerable magnitude which might prove really formidable in case of a collision with the nucleus itself. Moreover, Biela's

Comet is one of the so-called periodic comets of which there are only eighteen known to us; these return regularly to the sun in short periods, so that their orbits are closed curves like those of the planets, only more elongated, more elliptical. This particular comet crosses the earth's orbit every six and a half years. Of course, with so frequent a return the probability of a collision is greatly increased. These periodic comets therefore interest us especially.

We have proof that these comets have been captured by the planets, mostly moreover by the monster planet Jupiter; that is to say they have only been in the course of time permanently incorporated into the solar system. Originally they came as the other comets do from immeasurable distances in parabolic orbits. But their path passed lengthwise through the lens-shaped region occupied as described above by the planetary orbits. Such comets consequently remain much longer in the neighborhood of the planets than those which cut crosswise through the thickness of this lens. The former are obviously more dangerous, just because they stay longer near us. If such a comet approaches at all close to a planet that is moving in the same direction, the two bodies will continue near to-

gether for a rather long time with the result that the planet through the prolonged action of its gravitation will turn the comet considerably out of its original course. In this way the orbits of these periodic comets have become elliptical. Now it may seem at first thought as if this influence should be regarded with apprehension since it has the effect of detaining just these dangerous comets permanently in the planetary region. But on further consideration the very opposite is found to be true, for this very circumstance proves to be a protective provision against these dangerous bodies. It has been discovered that when a comet approaches very near to the sun or to a planet, its component masses, which in any case are held together more or less loosely, become drawn out or are even violently separated. Now if such a comet is forced, for the reason that its orbit has been disturbed by a planet and thus made elliptical, to return frequently to the sun, it disintegrates gradually. As it breaks up the particles scatter all along its orbit. In this way a monster ring of shooting stars, such as we referred to above, is formed. The comet as a result becomes wholly harmless. We saw, so to speak, before our very eyes how Biela's Comet split into two parts sep-

arated by a constantly widening interval. Afterward its particles became so scattered that it no longer appeared as a comet but instead was visible as a meteoric swarm. Other comets that came especially near to the sun have split up into several pieces. Again we see a group of comets traveling at considerable intervals in the same orbit so that they must have been produced by the disintegration of a single comet. Thus about the same thing happens here as when meteorites dashing through the earth's atmosphere are broken into pieces. The causal force is different, but the effect is the same: dangerous intruders are reduced in size and therefore made less dangerous.

It is wonderful to see how in the realm of inanimate nature too one finds these provisions for the stability of the general system of things which are so characteristic of the world of organic life. In an earlier work, *"Der Untergang der Erde und die kosmischen Katastrophen,"* which, though it is considerably more detailed in treatment, has practically the same subject matter as the present little volume, I tried for the first time to trace these forces that work for the preservation of heavenly bodies.

Such a captured comet must necessarily re-

turn at regular intervals to the same point in space where its course was first disturbed, and so very likely there will be another encounter with the same planet that originally captured it. The new perturbation which thus results is in most cases different from the first one and consequently it gives the comet an entirely new orbit. At times such an intruder is flung in this way completely outside the planetary region. A comet that reappeared not so very long ago, in 1903, furnishes an instructive illustration. This comet is a genuinely typical example of these cosmic rovers that are always changing their form as well as their course. It was discovered as Brooks' Comet in 1889. Its appearance—for it was split up into a large number of separate pieces—showed that it must have met with an unlucky adventure some time before. And, indeed, Chandler was able to prove by mathematical computation that three years previously the comet had approached so exceedingly near Jupiter that it must have shot midway through the planet's system of satellites if indeed it did not actually collide with the planet itself. Jupiter seemed in no way affected by the encounter; it did not depart even so much as a hair's breadth from its accustomed orbit. The comet on the

other hand was not only broken up into pieces, but besides its orbit was transformed into one having a short period of seven years which it has followed since, returning again in 1896 and in 1903. The further discovery was moreover made that, before the collision in 1886, the comet had an orbit with a period of twenty-seven years which did not bring it within range of vision for observations from the earth. Now four such periods of twenty-seven years make one hundred and eight years or as much as nine revolutions of Jupiter, which takes about twelve years to revolve around the sun. Consequently one hundred and eight years before 1886, that is in 1778 or 1779 (for the calculation is thus much uncertain), the comet must have collided with Jupiter and so gotten the orbit of twenty-seven years. This brings us to another comet that made the perplexed astronomers sweat hard as much as one hundred years ago: Lexell's Comet, namely, which was discovered in 1770 and which, according to mathematical reckoning, had a period of only five and a half years, though it was never seen before or after. Already at that time calculations showed that Lexell's Comet would have to encounter Jupiter in 1779, the same year designated by our computation for the

encounter with Brooks' Comet; and that the same thing must have occurred two revolutions previously (for two revolutions of this comet then equaled one revolution of Jupiter), that is, in 1767. It is consequently very probable that Brooks' Comet is identical with Lexell's Comet or is at least a fragment of the latter. Putting all these facts together we arrive at the following conclusion: In 1767 a comet coming from an unknown distance passed so near Jupiter that the disturbing influence of the planet changed the comet's orbit into an ellipse with a period of five and a half years which it pursued for but two revolutions when it was given a new orbit of twenty-seven years, which it completed four times, after which in 1886 it was again forced back into a short-period orbit, one of seven years, which it has since completed twice. After this comet shall have followed its present orbit through five revolutions, which are about equal to two revolutions of Jupiter, there will be a fresh encounter, which will throw the comet again into a different orbit until at last the intruder will be hurled wholly outside the planetary system.

This interesting example shows how an encounter between a comet and a planet resulted

disastrously only for the former; it alone was broken up and had its orbit changed. In the struggle for existence among heavenly bodies, too, superior strength wins out: if a weaker body strikes against a stronger one, it is shattered and flung back in fragments into the void.

Of course this holds true only of the larger orbs. But even though at such an encounter the planet is not affected as a heavenly body in any way that we can see from the earth, still this does not exclude the possibility that everything upon its surface may have fallen in ruins so that, from the human point of view, the comet was nevertheless the cause of the destruction of the planet. In the case of Jupiter in particular we can see absolutely nothing of the planet's surface. This orb is enveloped by an atmosphere that is considerably higher and denser than the earth's atmosphere. We see only the clouds of its upper air currents. This denser atmosphere is of course so much the more effective a protection against intruders. Still it looks as if in the past century toward the end of the seventies a catastrophe of this sort actually occurred on this the largest of the earth's sister-planets. In the clouds of Jupiter's upper atmosphere there appeared a red spot larger than the

whole of Europe. In the years immediately following it spread and grew brighter, then gradually faded, though even today it has not wholly disappeared. The spot was drawn out in the direction of the planet's rotation. Indeed all of Jupiter's cloud-formations are plainly influenced by this swift rotary motion. In the telescope Jupiter shows distinct parallel bands or zones marking the cloud-belts formed by its trade-winds. As this monster planet turns swiftly on its axis, the air lags behind the solid crust to a far greater extent than on our earth. Now it was observed that the "Great Red Spot" was slowly left behind the other visible markings; it seemed to be moving in the reverse direction over the planet's surface. Taking everything into consideration one could not explain the phenomenon except by assuming that underneath the cloud sheets, which alone are visible to us, Jupiter has a thin solid crust which broke open in the locality of the Great Red Spot, allowing the fiery lava to flow forth, whereby the clouds overhead were lit up with a red glow. The outbreak did not occur simultaneously over the whole region. We can readily imagine, in the light of our knowledge of similar catastrophes upon the earth, that the subsidence of so

large an area must have taken place gradually even though within the space of a few years. The magma, which issued forth therewith, was forced back just like the air only more slowly, in the direction opposite to the planet's rotary motion.

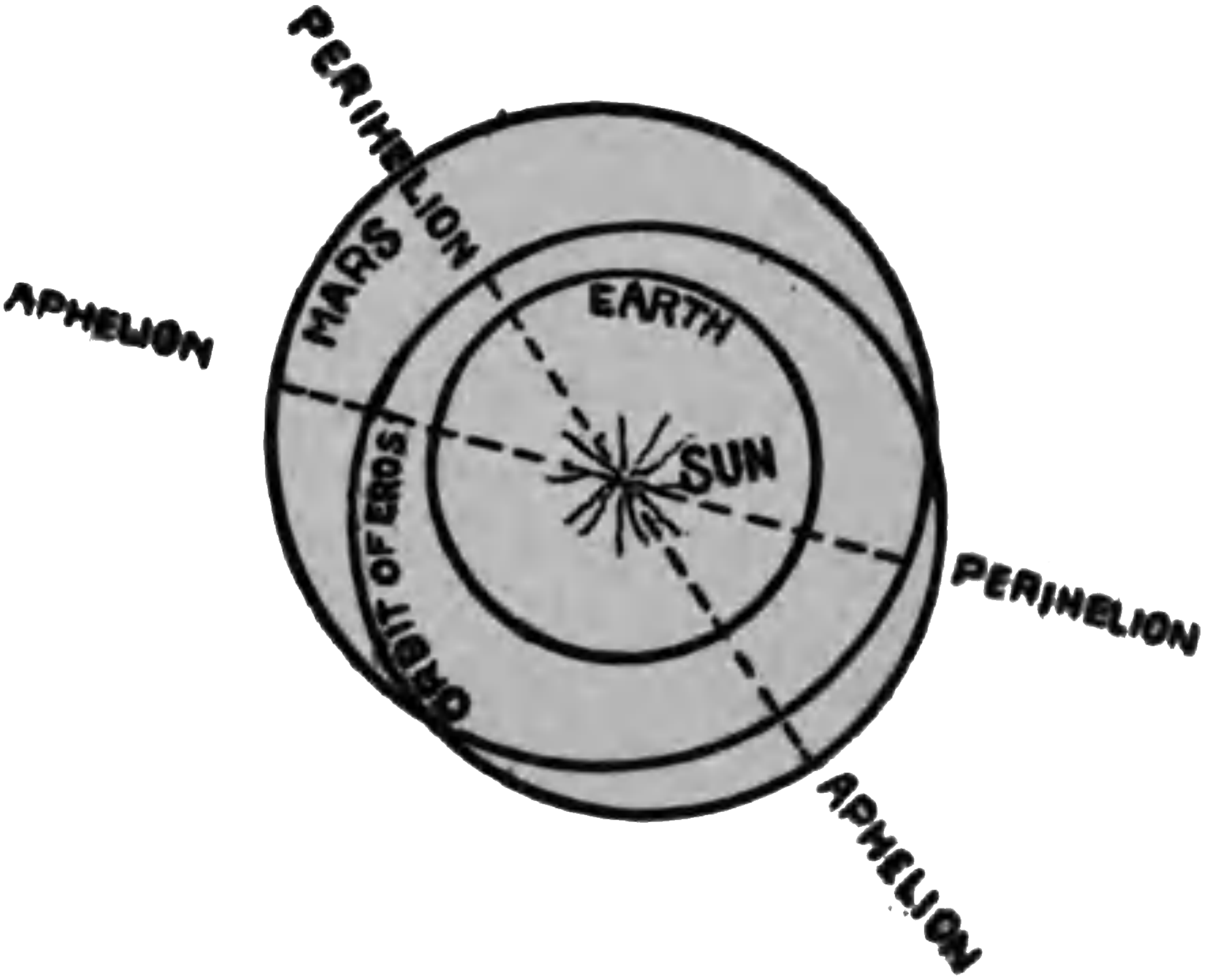
Is the original cause of this geological upheaval upon Jupiter to be ascribed to the impact of a foreign body coming from outer space, or can the phenomenon be explained as the effect of forces at work in the interior of the planet? The answer to this question is implied in what has gone before. In the case of the gigantic planet Jupiter, which is certainly still in an early stage of its evolution, it is far less likely than in the case of the earth, that inner tensions should accumulate so considerably as to produce such catastrophes. There is scarcely room for any other explanation than that a rather large body crashed down from outer space upon the thin crust and so caused it to burst open. The lava streams issuing from the fissure gradually flooded the crust in the vicinity so that, for a considerable space of time afterward, the reflection in the clouds overhead became brighter and brighter. However this may be, whether the destructive forces came from within the

planet or from without, in any case we have here a catastrophe of the same sort as, we are constrained to believe, broke over the earth toward the end of the Tertiary period. If Jupiter were already inhabitated by living beings, which is not probable, this event would have been fateful for them.

Jupiter's Great Red Spot may not seem to some to be convincing proof that a collision can occur between heavenly bodies; if not, we have other indisputable proofs in reserve. Very close to the earth there is a small planet which must be a fragment of some orb that was shattered through such a collision: *Eros*, namely, which was discovered only in 1898 by Witt at the Urania Observatory at Berlin. Eros evidently belonged at one time to the group of minor planets which revolve around the sun in the space between Mars and Jupiter. Through some catastrophe it must have been flung out of this belt so that, in its present elongated elliptical orbit, it approaches nearer the earth than any other planet. Only a small portion of its orbit is now beyond that of Mars. Such a catastrophe, which could thus hurl a body several miles in diameter many millions of miles out of its course, might conceivably have taken an unlucky

turn and caused this body to fly headlong against our earth, instead of only into its vicinity, although evidently the probability of such an occurrence is very small.

Eros has a peculiar feature which proves that this small planet is really a mere fragment of



an orb. Whereas all normal heavenly bodies are spherical in shape, it has corners where its different faces meet at angles with each other. We know this from the fact that it shows regularly

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alternating fluctuations of brightness, which cannot be explained except on the theory that, while the planet rotates regularly once every five hours and seventeen minutes, it turns therewith alternately toward us sides reflecting the sun's light with various degrees of intensity.

It is possible that this catastrophe, which split up an orb in the earth's vicinity, occurred not very long ago, for else it would be strange that we have only recently discovered this planet, which is indeed a rather bright object in the heavens at its periodic return to its position nearest the earth. The body that collided with Eros was probably not a comet or a meteorite, but another planet. For in the space between the orbits of Mars and Jupiter there is a thick swarm of tiny planets. Five hundred have already been counted and these doubtless constitute only a small fraction of the total number.

Already long ago it was surmised that all these small bodies were but the shattered remains of a larger planet which had met with an accident. But there came a time when every catastrophic explanation, indeed every explanation involving any unevenness of development, was discountenanced throughout the whole domain of science. Evidently this was an ultra-

extreme reaction against the previously prevailing theory of "catastrophism," according to which every geological age was supposed to have been begun and ended by a cosmic catastrophe so that a new general act of creation had to follow. Today we are convinced that in cosmic evolution, as in human life, things have not always gone smoothly, though on the whole there has been an orderly development; and more and more we reach the conclusion that such forces as are either partially destructive, or at least oppositional and obstructive, are an essential element in all evolution just as is the struggle for existence. We shall see later on how catastrophes are necessary for the rebirth of heavenly bodies; for here just as in organic nature every birth is attended with pain and has something of a catastrophic nature.

Today therefore we are again much more inclined to view this swarm of minor planets as the product of the shattering of a single orb. Among these fragments further collisions occur that lead to further disintegration. Fluctuations of brilliancy similar to those of Eros have been observed in the case of the other minor planets also, thus betraying their broken shape.

In all these instances what we actually see is

the effect of the collision of two heavenly bodies and not the collision itself. Three years ago however such a collision of a fearfully violent character actually took place before our eyes. It was by far the most imposingly magnificent phenomenon of the heavens ever witnessed by man. As a result of this occurrence a *new star* blazed up suddenly on February 21st, 1901, in the constellation of *Perseus;* or, more accurately, it was then seen there among the other fixed stars although the night before it was not visible to the naked eye and two days before it could not be seen even in the larger telescopes. For it happened that two days previously that particular region of the heavens had been photographed at an American observatory, but the plate showed no trace of the star. After its discovery the star increased more and more in brightness and the following night it had become the brightest star in the heavens with the exception only of Sirius. After that it faded, at the start very fast, then gradually. But intermittently it flared up again. These outbursts of brightness at first recurred regularly within a period that evidently signified a rotation of the brighter and darker sides of the star once about every four days.

What had happened? Had an orb split open allowing its white hot interior to gush forth like blood from a wound? Something of the sort must have happened. But here again if there were no further evidence at hand we might be in doubt as to whether the catastrophe was of interior or of exterior origin. In the first place the telescope revealed, not as one might expect the two stars whose collision caused the catastrophe, but only one star, a single distinct point without any measurable diameter like the other fixed stars. We have however another apparatus which is far more wonderful than the telescope and photography, the spectroscope namely which reveals not only the chemical make-up of the remotest heavenly bodies but even their movements in the direction toward or away from us which thus could not be seen in the best telescopes. Now in the case of this phenomenon in Perseus the spectroscope showed unquestionably that the light came from two separate bodies which were moving through space with very different velocities. One of the bodies had a normal velocity of about twelve miles a second like other fixed stars. For cosmic proportions this is not extraordinarily fast. But the other body whirled through space with a velocity at

least fifty times as great, that is, at a rate of about seven hundred miles a second; in thirty-five seconds such a body would fly around the earth. The two bodies were moving in opposite directions; with such inconceivable might had they crashed against each other. Everything must therewith have been ground to dust and transformed into luminous gases.

According to another view the original velocity of the impinging body was not so considerable. In this case it is supposed that a dead non-luminous orb in its course through space penetrated into a swarm of shooting stars or a cloud of meteors. The smaller bodies were attracted by the larger intruder and dropped toward it with an accelerating velocity that finally reached the rate of seven hundred miles a second. At the same time part of the swarm developed a revolving motion which produced the periodic fluctuations of brightness before mentioned. This interpretation of the occurrence makes it seem scarcely less awful, when one considers that in this case the solid orb was bombarded by millions of millions of small bodies having a velocity of seven hundred miles a second.

But another strange thing happened to the

new star. In the course of a few months it became enveloped by a nebula which gradually spread out more and more around it extending farther and farther into space. This may not seem very wonderful in itself after one has realized the tremendous violence of the collision. The nebula was in fact formed by the gases into which at least part of the mass of the colliding bodies was transformed at the impact. To this however was added the fact that the nebula spread around the new star, which had now faded to a dim speck of light, with a velocity that was incomprehensible even according to cosmic standards. The reader can convince himself of the reality of all this by studying the accompanying cuts. They represent two stages of the nebula, in which one can clearly see the progress of particularly dense spots in the interval between the representations if one compares them with the location of the fixed stars near by. The particular region under consideration is inclosed in both cuts by a circle. If one notices the groups of stars within each circle one can, by making comparisons, realize from the cuts the extent of the movement as it appeared from the earth. From this apparent movement one can calculate the actual movement in miles

per second as soon as one knows the distance of the star. This distance has been found by careful measurement to be so enormous that it takes light several centuries to reach the earth from that star; the occurrence which we observed in 1901 must therefore have taken place in centuries long gone by. For such distances, it is true, our measurements become very imperfect. Still we can always fix a minimum and say, that the star must be at least so and so far away from the earth; it cannot then be any nearer, though it may be considerably farther away. Thus from the apparent movement of the denser spots in the nebula around the new star, we can calculate the minimum of the actual velocity, which can only be surpassed by the reality. The astonishing result is thereby obtained that the luminous emanations were ejected for months into space with the actual velocity of light, that is, at the terrific rate of 200,000 miles per second. In a short time they filled up a region more than a thousand times as large as that occupied by our entire solar system.

For a long time the reality of these facts was questioned. They were altogether too far removed from all experience up to that time. The distribution of nebulous matter must indeed have

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Nebula around the new star in Perseus, photographed on Dec. 8 and 11, 1901, at the Lick Observatory, in California. See page 107.

taken place three hundred times faster than the velocity of the impinging body which caused the catastrophe, a velocity which itself belongs to the class of unusual ones even in interstellar space. It was therefore surmised that the distribution might be only apparent, that the nebula had existed always but had previously been dark and only became gradually illumined when the star within it blazed up so brightly. Thus at this tremendous distance we had seen light rays with their velocity of 200,000 miles per second creep every day no more than a hair's breadth over the nebula. Everything looks smaller from a distance and so light waves, which actually traveled in an instant over inconceivably great distances, seemed almost to stand still. Probably nothing else can so impressively make clear to us the awful immensity of the universe that lies within our vision, as this slow extension of the light over the new nebula in the constellation of Perseus.

Now there can be no doubt but that the velocity of this extension was actually that of light. The theory stated in the preceeding paragraph has however been seriously called into question. The manner of the distribution of luminosity in the direction at right angles to the line of vision

led to grave doubts. Moreover particular spots of light could be seen all too clearly moving farther and farther away even in a distinctly spiral-formed path. In spite of theoretical difficulties the conclusion could not be avoided that, as a consequence of the inconceivably violent collision, actual matter must have been hurled into space from the centre of impact with the velocity of light.

A recent discovery in an entirely different field has moreover thrown light upon that phase of this catastrophe which had thus far baffled scientific explanation; it must be admitted though that we are here summoning a phenomenon which is itself an unsolved problem to clear up another difficulty. It is possible that the irradiations of *radium* play a part here. According to the latest results of scientific investigation atoms of radium are minute worlds which, like the new star in Perseus, are undergoing disintegration. It has been demonstrated that from every atom of radium tiny particles called *ions* emanate with the velocity of light and make everything in their vicinity that they strike luminous. They thus spread about themselves a luminous cloud exactly like the puzzling nebula of the new star. These ions, also called *elec-*

trons because of their electric nature, are about two thousand times smaller than the smallest chemical atom, that of water. Thereby the fact, which was surmised long ago, is demonstrated, that chemical atoms do not deserve their name of being the ultimate indivisible units of matter. Like the molecules into which they combine, atoms are organizations of minute size, in which the constituent particles move about in orderly systems just as the heavenly bodies do in space. In my larger work, *"Die Naturkräfte, ein Weltbild der physikalischen und chemischen Erscheinungen"* (Leipsic, 1903), I have tried to give a popularly intelligible account of the principal points in these interesting relations and parallelisms between atoms and heavenly bodies. Now it seems that radium is an atom in which the movements of the constituent electrons have for some reason fallen into disorder, so that these tiny orbs constantly strike against one another, with the result that many are thrown entirely outside the atomic system. The radium atom is evidently in process of disintegration; its emanations signify the ruin of a minute world in the lowest stage of the organization of matter. Into this microcosmic world the human eye cannot penetrate; it discloses its

wonders only to the prying intellect. The radium atom is one of the largest atoms known to us. It must be composed of a half million electrons or ultimate units of matter; each atom is thus a minute galaxy in which the swarming suns, represented by the electrons, jostle one another. In this connection it is interesting to notice that it is similarly in the neighborhood of the Milky Way that most of the collisions between heavenly orbs occur which give rise to those "new stars" among which the one that blazed up in the constellation of Perseus is the largest and the most wonderful since the appearance of Tycho's Star in 1572. It may be that the radium atom has developed under different circumstances to such a size that it cannot persist under the normal conditions that obtain on the earth's surface and therefore must resolve itself at least partially into its original units, the ions or electrons. Atoms are therefore not unchangeable. Indeed we have thus far been unable to point out anything that does not suffer change. Atoms, too, probably have to pass through a development from formation to decay; like every other organization of matter, they have their beginning and end.

Radium is one of the rarest elements known

to us. It is found in small quantities combined with other rare and likewise heavy elements as, for instance, uranium. The heaviest substances tend to sink deepest and on this account alone we might reasonably conjecture that in the deepest part of the earth's interior, farther down than we have ever penetrated, radium may perhaps occur in larger quantities. And indeed many considerations support this conjecture. For example it has been observed that the air in mines is exceptionally full of the luminous substance which emanates from radium, or rather, into which radium disintegrates. It seems natural to suppose that irradiations of radium constantly ascend from deep within the earth's interior and, because of the extraordinary lightness of this product of atomic disintegration, scatter at once escaping finally beyond the earth's atmosphere into outer space. According to the latest investigations made by Ramsay, radium gradually decomposes into helium, the second lightest known element, which is likewise rarely met with on the earth and this for the reason that its atoms are too light to be effectively held fast by the earth's attraction. The fact that helium is permanently present in our atmosphere, even though in but small quantities, proves that the

supply must somehow be replenished. The conditions that obtain on the sun are very different; the sun's attraction is considerably stronger than the earth's, and so its upper atmosphere is made up almost entirely of helium which received its name from this circumstance. It was discovered there long before any traces of it had been found on our globe, through a line in the solar spectrum which was different from the spectra of all terrestrial elements. The sun's helium atmosphere confirms the conjecture that the interior of heavenly bodies contains larger quantities of radium, which perhaps can be formed from ions only under the tremendous pressure that prevails there, and which, as it rises and is liberated from that pressure, decomposes again.

When, therefore, two heavenly bodies meeting in violent collision are so shattered that their inner masses fly into space, the radium, which was before concealed deep within, must begin at once to send forth its wonderful irradiations, in the same way in which radium acts in our scientific laboratories where we can observe it close at hand. Therewith the material of these orbs is decomposed into the original sub-atoms, the so-called ions or electrons, which scatter into space with the velocity of light. A new nebula comes

into existence before our eyes made up of the very smallest and simplest units of matter having no connection whatever with one another. Primordial conditions are thus reinstated. A heavenly body has undergone a destruction of the most radical kind. All system and order has been destroyed even down to atomic organization. And we ourselves witnessed such a dissolution when the new star blazed up in the constellation of Perseus. Here we have then a definite answer to the question under consideration: *Is a destruction of a heavenly body possible and what can cause it?* Stars may crash together with such violence that, in the resulting ruin, not even the smallest stone in the imposing structure remains standing upon another. Even the atomic systems are resolved into separate ions. All this takes place unexpectedly within the space of a few hours. The thought of the suddenness of such a catastrophe makes one shudder, yet this very circumstance would prove a blessing, should such a calamity ever visit an orb which, like the earth, is inhabited by living beings.

In view of these facts it becomes a burning question for us, whether our earth could be visited with a similar catastrophe. Evidently a

heavenly body can be completely destroyed only by a collision with a body of like magnitude. The masses and velocities of the colliding bodies have to be tremendous. Now as far as we know the only bodies of like magnitude with the earth are the other planets which follow, at a distance of millions of miles from us, fixed orbits in which they can never come into contact with each other. The nearest star, moreover, situated in the southern portion of the constellation of Centaurus, is so enormously distant that it takes light four and a half years to reach us from it. The stars are surrounded by immense regions of empty space in which they can develop undisturbed. There is therefore no reason for apprehending a destruction of the earth in the near future through a collision with any known heavenly body. But there are doubtless many dark orbs in space which must remain forever invisible to us. Meteorites offer tangible proof of their existence. Thus we see how our inquiry regarding the possibility of a destruction of the earth always leads us into the domain of the unknown.

It would be impossible however for bodies of any considerable magnitude, even if they were totally dark, to come near to the earth without

being noticed. They would betray their presence through their power of attraction; just as Leverrier discovered Neptune, in the forties of the past century, merely through the influence of its gravitation upon Uranus, so an approaching orb could be located by mathematical calculation while still at a considerable distance. At present there is not the slightest evidence of anything of the sort; so for the time being at least we need not feel uneasy.

But how will matters stand in the future, after thousands or even millions of years have passed by? All suns, including our own with its train of planets, move forward in space, and that in a straight line, as far as we can tell from observations covering so short a period. The bright star Vega, which is one of those nearest the earth, would reach our planet in fifty thousand years, if its present known movement were directed straight toward us. In reality however this is not the case. The great system of the Milky Way clearly reveals a unified organization, as we shall see in another volume of this series in discussing the origin of heavenly bodies; and it can scarcely be doubted that the suns of the Milky Way move in orbits similar to those of the planets, so that collisions are impossible as

long as the general order remains undisturbed. It is therefore not easy for the stars to destroy one another.

Still the appearance of new stars shows that such collisions occur nevertheless. Moreover these occurrences are not so rare as was formerly believed. Ever since we succeeded in scanning the heavens more narrowly by means of photography we notice, far more frequently than use to be the case, new specks of light appearing among the teeming numbers of stars. These new stars occur most abundantly where the stars seem to be thickest. Of course one must not forget that millions of stars continue unchanged and that therefore, even if every year one new star blazes up among a million old ones, any one star in the million suffers such a vicissitude but once in a million years. Still the thing does happen as observation shows. Moreover the circumstance that new stars occur oftenest in those regions of space where the stars are packed thickest, proves that we are dealing here with actual collisions and not with outbreaks caused by inner tensions which could not have any connection with the clustering of the stars.

Now our own sun, too, belongs to the system of the Milky Way, which in fact includes, ac-

cording to the latest views, all stars visible to us; but it is situated in the comparatively empty center of this monster spiral of swarming suns. It looks as if the order, under the protection of which our planet took form and developed, were destined to continue undisturbed forever.

It is impossible though that anything which has had a beginning should actually last forever. Even though our solar system may persist for untold millions of years, sometime it too must grow old and die. After that it too will have a rebirth, for in nature there is no eternal stagnation. But how in the normal course of things will the earth and the solar system come to an end?

We know that the earth's surface was once considerably hotter than at present. The cooling off of the crust is a normal process which is going on upon all heavenly bodies having a high temperature, for the reason that they hang in cold space where a temperature of four hundred degrees Fahrenheit below zero prevails. On the other hand we have seen that, in the case of heavenly bodies which, like our sun, have a low density and are therefore still susceptible of considerable compression, the pressure of their own mass can generate more heat than they radiate

into space, so that they become hotter and hotter. But this process cannot go on forever. As the orb becomes denser, in consequence of the action of its own gravitation, its capacity for further compression is diminished and consequently always more heat is radiated in excess of what is generated until at last, after the maximum density has been attained, generation of heat ceases and only radiation continues. Unless contrary influences intervene all heavenly bodies must, in the course of time, cool off to the temperature of space and naturally this happens first on the surface, which is the part inhabited by living creatures. The moon has already nearly reached this stage. The average temperature of its crust is known to be about 120 degrees Fahrenheit below zero, whereas that of the earth's crust averages about 60 degrees above zero. The moon has therefore cooled off about 180 degrees more than the earth. It is true that the moon is not protected against the icy cold of space by an enveloping atmosphere without which our earth too would be considerably colder. But on the other hand the moon's surface is directly exposed to the burning rays of the sun, which shines on the moon uninterruptedly for fourteen days, so that the tempera-

ture at the lunar noon may perhaps rise above the freezing point and it is possible that a scanty life may then develop in isolated low-lying places where some air may be left. In recent years several investigators in this field have claimed that they saw traces of it. However this may be the moon is unquestionably a world that has succumbed largely, if not entirely, to the invasion of the icy coldness of space. The moon on account of its smaller size had to radiate its heat faster than the earth and a shorter life-span was therefore allotted to it. Still there can be no doubt that the earth will die a similar death unless some catastrophe intervenes. We see with astonishment how nature seems to be preparing for this event, for instance, by interspersing ice ages in the last geological period as if to bring about in the world of living things, as far as possible, a better adaptation to the inexorable encroachments of the icy coldness of outer space. Indeed it has been demonstrated in late years, since we have learned to create artificially temperatures as low as 420 degrees below zero, that cold of itself does not destroy the life of germs or of micro-organisms. Even though, with increasing coldness, the manifestations of life are limited within ever narrower

confines, still vitality itself is not lost. Cold cannot entirely destroy organic life on an orb, though it can restrict the play of vital activities and finally even make these dormant. There can be no doubt that the terrible coldness of icy space will some time enwrap the earth and all other heavenly bodies, provided they do not come to a premature end through some catastrophe. In the terrific ice-ages that will come and go, whole races of living creatures will perish one after another; the human race, and possibly even more perfect beings which may follow man in the scale of evolution, will be forever wiped off the face of our planet. Still a complete destruction of the earth, in which *all* organization would be dissolved, like what took place when the new star broke out in the constellation of Perseus, can never be caused by cold alone. On the contrary cold preserves the simpler organisms perfectly. In the end the whole earth, or whatever heavenly body it happens to be, becomes as it were a single monster seed that lies over winter in the cold ground awaiting germination with the return of spring.

But before this state is reached, life with its infinite resourcefulness will have found an abundance of ways for winning new domain from

grudging nature. Precisely this struggle with the monstrosities of nature has permitted the development of the human mind which has learned more and more how to subdue these hostile forces and to compel them to enter into the service of life. From early times the human race was able to live in countries where the temperature in winter is not much above the average temperature of the dead moon. Moreover it is conceivable that the development of life need not depend always, as it does under present temperature conditions, on the existence of water in its three states and of air having the composition of our present atmosphere. It may be that, with an average temperature considerably higher or lower than at present, quite different chemical elements might develop a similar mutual interaction adequate for the development of life on the earth. A world of entirely different living creatures would be the consequence. We need not pursue this speculation further. Suffice it to say that in any case the germs of life are preserved during a gradual lowering of the temperature to the lowest conceivable temperature, namely that of 470 degrees Fahrenheit below zero. Therefore we can say with complete certainty, not merely with considerable proba-

bility as we did in foregoing discussions, that the earth cannot be totally destroyed as a result of the normal process of the cooling off of its mass.

But what happens afterward? What brings the return of spring when all the orbs round about hang in the icy-cold heavens frozen, rigid, inert? Is not this equivalent to an eternal death? The sun too must finally grow colder and colder. Where shall we look for a new source of light and warmth without which living things cannot develop?

Nature has numberless remedies. In the case of the smaller orbs, the moons which revolve around the planets, meteorites seem to play an important part in replenishing the heat on the surface; this is notably true of our own moon. In the course of time, as a heavenly body grows older and consequently colder, chemical, as well as vital, processes use up its atmosphere so that, as we have already seen, meteorites can penetrate to the surface much more easily. If for instance a rather large meteorite should drop upon the moon's surface, we know that the blow would fracture the crust in the vicinity and reduce it to a red hot fluid. Now the moon's frigid crust is probably stored with germs of life left over from an earlier age, when organic life flourished

on it. In the immediate neighborhood of the impact every germ of life it is true would be annihilated, for heat, unlike cold, when excessive, dissolves all organization even that of atoms. But on the other hand the fiery magma would spread over the surface melting the ice upon it and forming gases that would replenish the atmosphere where it had long since been exhausted; in short all the conditions for the growth of organic forms would be reinstated so that the germs which still remained alive could develop. This explains why certain changes of color on the moon, which are thought to be due to a vegetation that grows up at the lunar midday, have been observed only in the basins of craters; for these depressions mark the spots where meteorites once fell and where the greatest amount of the heat then produced is still left. Besides water can collect easiest in these crater holes. Thus the fall of a meteorite which is so much feared as the possible cause of the destruction of an orb becomes for a dying world the means of renewed life. And it is wonderful to see how nature has arranged that dying orbs, which benefit by the falling of meteorites, are easily accessible to them, whereas heavenly bodies, which are still in the full bloom of life and

which would suffer considerable destruction through large meteorites, are as far as possible shielded against these intruders.

Another of nature's devices for getting the full benefit from what heat there is, consists in the gradual nearing of the planets to their respective suns and of the moons to their planets. It is true that, in accordance with the laws of gravitation which govern all heavenly bodies, the present order of our solar system must continue unchanged for many thousands of millions of years; and in particular that the distances of the planets from one another and from the sun cannot vary, as long as these laws remain valid and no foreign masses of great magnitude invade our system from without.

Space, however, is not empty. It is filled with meteorites, swarms of shooting stars and nebulous matter; and these must offer resistance to the movements of heavenly bodies. The monster clock-work of the heavens, for all its seeming everlastingness, becomes gradually clogged with dust too, and the necessary consequence of this is, that the heavenly bodies slowly but steadily move closer together. The moons must constantly come nearer to their planets, and these to their respective suns; and ultimately even the

suns must move closer together. The complex of heavenly bodies, constituting the great stellar systems, behaves exactly like a single orb which is indeed, in its atoms and molecules, likewise a complicated system, a galaxy, as it were, of tiny orbs moving according to fixed laws at definite distances from one another. The universal tendency of masses is to become more and more compressed in the course of time.

The decrease in the amount of heat radiated by the sun is thus offset by the greater nearness of the planets. The same thing is true of a planet and its moons. When the smaller bodies have cooled off enough to sustain life, the surface of the planet is still burning hot. To a certain extent this condition obtains at present in the case of Jupiter and its moons.

Nature has made another simply wonderful provision whereby a secondary orb uses to the best possible advantage the diminishing supply of heat radiated by its primary. After the moons have moved considerably closer to their planets, or the planets to their sun, the larger body begins to influence the smaller secondary one in such a way that its rotation upon its axis is gradually retarded until at last this occupies as much time as the revolution around the primary orb. When

this state is reached, the secondary orb always keeps the same side turned toward its primary, just as our moon does today and probably the moons of the other planets too. As long as the primary radiates a considerable amount of heat, the secondary orb rotates very swiftly upon its axis so that every part of its surface is exposed for only a short time to the burning rays, lest all life upon it should be destroyed by the excessive heat. But in proportion as the radiation of heat diminishes, the secondary body exposes its surface for a longer and longer period at a time to the rays of the primary; its day becomes increasingly long until finally it turns always one and the same side to the central source of warmth, so that at least half of its surface may absorb an amount of heat sufficient for the development of life before all living things must perish with cold. In the case of the two planets nearest the sun, Mercury and Venus, this state has, it is supposed, been reached already; though of late the correctness of the observations, on which this supposition is based, has been called into question.

The force which draws heavenly bodies always closer together will in the end cause the moons to drop upon their planets and these again upon

their respective suns. The moons will first unite with the planets because the distance they have to cover is shorter. All the planets with the exception of the earth and of Neptune, which is the planet farthest from the sun, have more than one moon, if they have any at all. Mars has two satellites, Jupiter five, Saturn eight, and Uranus four. It can scarcely be doubted that Neptune too has several moons, which are invisible to us on account of their great distance from the earth. Now when a moon drops upon its planet, the consequence, unless the moon is exceedingly small, is a catastrophe which, humanly speaking, amounts to a destruction of the larger body. Each planet has to undergo as many such cataclysms as it has moons. One such visitation is therefore inevitable for the earth.

However this catastrophe will not break over us until the way has to some extent been prepared for it. Preparations against its coming are made by nature a long time in advance in order to mitigate as far as possible its destructiveness. The nearer the moon comes to the planet, the smaller its orbit becomes and the faster the velocity of its revolution. Then, if the moon is not too small, the same thing happens as when a comet approaching too close to the sun

is split up through the conflicting attraction of the nearer and farther parts. However solid the orb may be, it gradually breaks up into pieces, scattering its debris along its entire orbit in the same way that a comet does when it gradually forms into a monster ring of shooting stars.

Taking all things into consideration, one can scarcely doubt that the rings of Saturn represent the product of the disintegrating action of gravitation upon a number of the planet's moons. It has been demonstrated that these rings are composed of tiny separate particles each having an independent movement of its own. The innermost of the rings is semi-transparent. This "gauze ring," as it is called, is probably made up of particles of matter which originally belonged to the luminous outer rings but which lost part of their centrifugal force in collisions and are therefore now dropping in a spiral path upon Saturn as meteors of a special kind, which probably do not injure the planet any, since it is protected by a very dense atmosphere. It is quite possible that in the course of time the material of the entire ring will gradually unite with the planet in this way without producing any kind of a catastrophe.

When, however, the moon in question is very

small, it is subject, if at all, only in an insignificant degree to this disintegrating action of gravitation, which is comparable to the effect of the moon's attraction by which ebb and flood tide are produced. Smaller moons can therefore fall as such upon their planets. And such a moon may yet be large enough, not merely to destroy all life upon the planet, but even to heat the planet to lively incandescence so that to distant worlds it appears to blaze up suddenly as a new star that fades away only after many months or even years. But long after it has stopped radiating light, the planet continues to be a source of warmth for its other moons. Thus the destruction of the one moon was the means of preserving the vitality of the others. It was not in vain that the one orb was sacrificed. So too the sun must devour its own offspring, the planets, one after another in order to preserve the survivors as long as possible.

Now a multitude of circumstances argues that the earth once had another smaller moon which dropped upon it and thus caused all those upheavals that took place in the Tertiary period, when the great rupture along the Andes and the subsequent subsidence of the ocean floor of the Pacific occurred, the earth's axis was deflected,

the after-effects of which are noticeable in ea
tremblings even to this day, and finally,
a consequence of all this, the ice-sheets
the glacial age spread the silence of a de
like sleep far and wide over the earth. J
ter has at present such a small moon
is very close to the planet; some day, tho
may be it will be millions of years he
this moon must crash down upon Jupiter. So
time in the future, astronomers will be
to foretell the exact date and the generation
the human race then living upon the earth
witness on a neighboring world a catastroph
this sort, which was to be foreseen and whic
destined to produce a geological upheaval th
But this moon too will not under any conditi
be able to destroy all life upon a planet like Ju
ter, just as the earth's hypothetic moon cc
not. It could do no more than interpose a l
rest in the rhythmic movement of the ear
evolution and indeed it looks as if, as we s
before, the absorption of a moon into its pla
could never cause a cataclysm of a very rad
kind, or at any rate could do so only in exc
tional cases since, whenever the size of a seco
ary orb relative to its primary exceeds a cert
limit, the satellite is first broken up and tra

formed into a ring. It will thus be impossible for our present moon to fall as such upon the earth. If it could, it would certainly generate thereby such excessive heat that all life upon the earth's surface would be annihilated; and aside from this the shock of the impact would itself reduce everything to ruins. But long before the moon will finally reunite with the earth, it will have disintegrated into a ring encircling our planet, thus giving the sky, as it will be seen by future inhabitants of the earth, a most peculiar appearance. Such wonderful changes the sky itself must undergo in the course of geological ages, though, to us ephemeral creatures of a day in the everlasting process of cosmical evolution, it seems so unalterable. Already today the moon shows the beginning of such a transformation. It is elongated in the direction toward the earth so that it has an approximately egg-shaped form. The earth holds it firmly along this longer axis so that it oscillates only a very little to and fro about the line of direction toward the earth. As the moon comes closer to the earth this elongation must be constantly increased until finally material like dust, sand and rocks begins to break off at the pointed end, scattering gradually along the entire orbit. Thus we see how in this

stage of cosmical evolution too nature works for the preservation of existing heavenly bodies whenever this is at all possible.

The same interplay must take place between the sun and the planets. One after another the planets will have to reunite with the sun. And whether a planet drops all at once, or whether it is first transformed into a ring and then falls piecemeal very gradually, the result will be essentially the same: in far-off future ages the sun's diminishing supply of life-giving heat will be replenished, in the one case suddenly therewith causing the sun to flare up brightly as a new star, in the other slowly in gradual additions.

Still some time the last planet will have dropped upon the sun and the last particle of heat thereby generated will have been radiated into space. All the material which upbuilt the splendid sun and its train of planets, with all their richly varied life, will have become a single monstrous mass, cold, dark, inert, rolling through the empty void of space without end, without aim. This is the last, the very last, end of the solar system. Is there anything that could ever again awaken it to new life after its life-giving heat has been thus completely spent?

All bodies move restlessly through space. There is no star in the heavens that stands still. Whatever else may befall it, it moves on and on. Even after it is dead and burnt-out it continues on its way. The terrific force that impells it survives through all the catastrophes which it undergoes. But the dead orb cannot transform this energy of motion into vital power for itself, since only a difference of motion can set up a movement to and fro among the rigid particles of which the cold burnt-out sun is composed. But by virtue of inertia, the universal property of matter, every change of motion requires the action of a resisting force. And this force is lacking as long as no body from without acts on that dead mass.

Now we know what inconceivably great intervals of space separate the stars at least in that portion of the Milky Way in which our sun (itself of course also a star) is situated. Thousands of millions of years will certainly have to elapse before any two such stars can move so close together that their mutual attraction will cause movements to and fro among the component particles of their masses. Still finally this will come to pass. If the two stars do not pass very close by each other in their course, they

will merely disturb a little each other's orbit and then move apart forever. The occurrence then signifies nothing but an episode in the life-history of each orb. The case is different if the two suns come so close together that one of them enters within the sphere of attraction of the other's planetary system. In this case it may happen that the larger of the two suns will force the smaller to become its vassal, just as our sun, with the aid of its planets, captures comets. The result is a double star system in which the one orb revolves around the other in an elongated elliptical orbit; for similar reasons the orbits of periodic comets are likewise generally much elongated. Such *double stars* are numerous in the heavens, and all have this characteristic feature of elongated elliptical orbits, which shows that the two stars are associated loosely, not bound one to the other like Jupiter is to the sun.

Many of these binaries, as these pairs of stars are also called, lie exceedingly near each other, and indeed there are a vast number of instances where a binary looks like a single star even in the best telescopes, while in the spectroscope it is separated into its two components which revolve, usually very swiftly, in close proximity

around each other. Then again there are orbs which, like the famous star *Algol* in the constellation of Perseus, increase and diminish in brightness with such precise periodicity that this can only be explained by the assumption that a dark orb revolves around a self-luminous one thereby partially obscuring its light for us, as our own moon does during eclipses of the sun. Moreover the facts of the case argue that the difference in magnitude between the two bodies must be small and that the pair must be so exceedingly close together that they almost touch each other. Here then there are two suns—one dark, burnt-out, the other luminous, wrestling with each other in deadly conflict. Two bodies of nearly equal magnitude came too close together and in the ensuing struggle, being too equally matched, both must succumb, to form however, out of their fusion a new world. The collision is unavoidable. And it is possible that one of the stars is encircled by a ring, formed by the disintegration of its planets, in which the other star may be caught, thus precipitating the final catastrophe.

This fusion signifies the end of two worlds and the beginning of a new larger one. Whatever latent germs of life may have been pre-

served upon either of the two stars, are forever destroyed and, if the interpretation given above of the phenomena attending the appearance of the new star in the constellation of Perseus is correct, then even all chemical combinations, all atoms, will be resolved into the ultimate indivisible units of matter, the electrons. With the greatest possible velocity, that of light, these electrons fly into space, having regained their maximum living energy with which they are about to upbuild the new world, as indeed, out of this living energy alone, they must have upbuilt the old ones. Herewith the last chapter in the story of the *End of the World* reaches its conclusion; for at this point begins the story of the *Making of the World* which will be told in a subsequent volume of this series.

But I cannot resist adding one more thought even though it is of the nature of an hypothesis as yet unverified. Doubtless an enormous stretch of time, even when measured by cosmical standards, intervenes before a burnt-out sun that has cooled off at least on its crust to the temperature of space meets another heavenly body of like magnitude so that it can be made over into a new world in the manner indicated. It is quite probable, in view of what we have learned thus

far about the matters in question, that this long interval of perhaps thousands of millions of years, during which a burnt-out orb, subserving no constructive purpose of nature, travels, a rigid and inert mass, through the dark void of space, is utilized to prepare the dead mass inwardly for the new era of development that lies before it, somewhat as, in the axil of the falling leaf, the new bud forms that it may be in readiness to unfold when, after the long winter, spring returns. We know that a terrific heat may prevail in the interior of a heavenly body long after its crust has become hard as rock. Even after its surface has cooled to the lowest possible temperature, the interior may consist of hot gases of course in a state of enormous compression. In proportion as such an orb contracts through cold and through the pressure of its own mass, the conditions under which radium can be formed are more and more realized; for it seems that atoms of radium can be developed and preserved only under the enormous pressure that prevails in the innermost interior of a heavenly body. It is therefore quite possible that the long interval between the death and rebirth of a star is utilized to develop in the interior of the orb radium and similar substances the smallest particles of

which, when liberated, disintegrate into the ultimate units of matter, the electrons. In the interior of an orb that is, so to speak, lying dormant over winter, there is formed a seed capsule which is destined to burst open, through the violent collision of two heavenly bodies, thus scattering abroad the seed of a new world, the electrons.

This brings us back to our starting-point where we compared heavenly bodies with living organisms. We saw that they too undergo development, that they are born, grow up and produce seed and die, that, in the struggle for existence from which they too are not exempted, they meet with mishaps and may even succumb to a violent death, but that still through all nature cares for them with motherly forethought and makes a thousand provisions to ward off as far as possible such disasters. We saw further, with especial reference to the conditions that obtain on our own planet, that, apart from outside influences, all the circumstances in the normal evolution of a heavenly body point to a safe growth to maturity, even though this development may be interrupted by many a catastrophe which the conflict of the diverse creative forces of nature makes inevitable. To be sure disturbing influences from without will always interfere more

or less with this peaceful development because the earth, like every other heavenly body, is not a separate thing shut off from the rest of the universe; but on the other hand we have seen that such influences, in so far as they are produced by *known* bodies, cannot cause the destruction of an orb like the earth. And it would surely be unspeakably absurd to live in constant terror of those unknown bodies which doubtless exist in space though, since they are invisible to us, we have no means of ascertaining whether or not they might prove formidable. Still just as certainly as a well organized orb like our own cannot easily meet with a violent, premature end, so surely do we know that it, like everything else that has had a beginning, must ultimately face dissolution. But here, just as in the world of living organisms, death does not signify a final end. The atoms merely surrender one form of organization, in which they have expended their living energy, in order to enter into another different combination. Every death is at once a rebirth and out of dissolution springs new life.

Even though, in the fierce struggle for the material or ideal goods of the world, the individual often has to succumb so that for him the end of all has come, still he was but an atom in the

cosmos and his death contributed to the life of the universe.

Everything that is subserves the All. Disaster and, in the highest degree, death are things necessary and salutary in the evolution of the world. In higher knowledge, death is more and more stripped of its terrors.